WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAMS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

JUNE 1972

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

1 December 1972

SUBJECT: Charles River Dam, Boston, Massachusetts, DM No. 8, Cofferdams

HQDA (DAEN-CWE-B)
WASH DC 20314

1. Transmitted herewith are three copies of Supplement No. 1 to Design Memorandum No. 8, Cofferdams, Charles River Dam, Boston, Massachusetts.

2. This supplement has been prepared to incorporate revisions required to permit installation of relief wells inside unwatered cofferdam areas as discussed at conference held at NED on 24 October 1972 with Mr. Ralph Beene (DAEN-CWE-S).

FOR THE DIVISION ENGINEER:

Incl
as (in trip)

JOHN WM. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAMS

SUPPLEMENT NO. 1

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASSACHUSETTS

DECEMBER 1972

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

SUPPLEMENT NO. 1 TO DESIGN MEMORANDUM NO. 8

COFFERDAMS

DECEMBER 1972

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LIST OF PLATES

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

SUPPLEMENT NO. 1 TO DESIGN MEMORANDUM NO. 8, COFFERDAMS

DECEMBER 1972

S-1. PURPOSE. The purpose of this supplement is to present design revisions which are necessary to permit the construction of relief wells inside unwatered cofferdam areas and to update cost estimate items associated with relief well work.

S-2. SCOPE. This supplement contains revised relief well layout and details, requirements for ballast fill, revised piezometer requirements and revised cost estimate.

S-3. SUMMARY. The installation of relief wells can be done in unwatered cofferdam areas if a ballast fill is placed prior to unwatering. The purpose of the ballast fill is to weigh down the foundation areas where the water pressure in the rock could become high enough to uplift the overburden soil. Once relief wells are installed, most of the ballast fill can be removed. The construction of relief wells in unwatered areas is easier to do, easier to inspect, and does away with the difficulties and uncertainties associated with underwater work done from a floating plant. The cost estimate indicates that the cost of relief well construction inside unwatered cofferdam areas is about $150,000 lower than the cost for construction from floating plant.

S-4. BALLAST FILL. The locations of ballast fills are shown on Plates 8-17 and 8-18. The required thickness of ballast fill was computed for a minimum safety factor of 1.1 against uplift induced by water pressure at the rock surface assuming 100% static head measured from rock surface to design flood level counteracted by the weight of the soil above rock surface. Assumed unit weights are as follows:

water	64 lbs/cu.ft.
till	149 lbs/cu.ft.
silty sand (or natural soil other than till)	100 lbs/cu.ft.
ballast fill material	120 lbs/cu.ft.

The ballast fill material will consist of gravelly sand or sandy gravel meeting the gradation requirements of gravel fill material for the permanent work. The material will be placed by dropping through about 10 to 30 feet of water on areas previously dredged of soft material. The ballast fill material within a cofferdam area will be removed above El. 84, after all the relief wells within that cofferdam area have been installed and are operating adequately.

S-5. RELIEF WELLS. The relief wells will be installed after the ballast fill is in place and the area inclosed by the cofferdam is unwatered. The top of each well riser pipe will be cut off 2 feet above the ground surface adjacent to each well. Upon satisfactory installation of all relief wells within a cofferdam area, the ballast fill will be removed above El. 84. A small quantity of ballast fill material will remain above El. 84 to ensure adequate counter weight for the 1.1 safety factor against uplift. Prior to excavation for the structures within 50 feet of relief wells R-69 to R-80 in Stage 1 cofferdam, and R-26 to R-32 in Stage 2, submersible pumps will be installed inside alternate wells of the above rows and the water level will be pumped down and kept at 10 feet below rock surface at each pumped well. Unpumped wells will serve as open-end standpipe piezometers. The water level inside pumped wells will be kept 10 feet below rock surface until structural floor slabs are completed at which time the riser pipes will be cut off one foot above top of concrete. Relief well discharge will flow by gravity to water collection sumps. The requirement for grouting relief wells after flooding of the cofferdams remains unchanged. Relief well layouts and details are shown on Plates 8-17, -18 and -19.

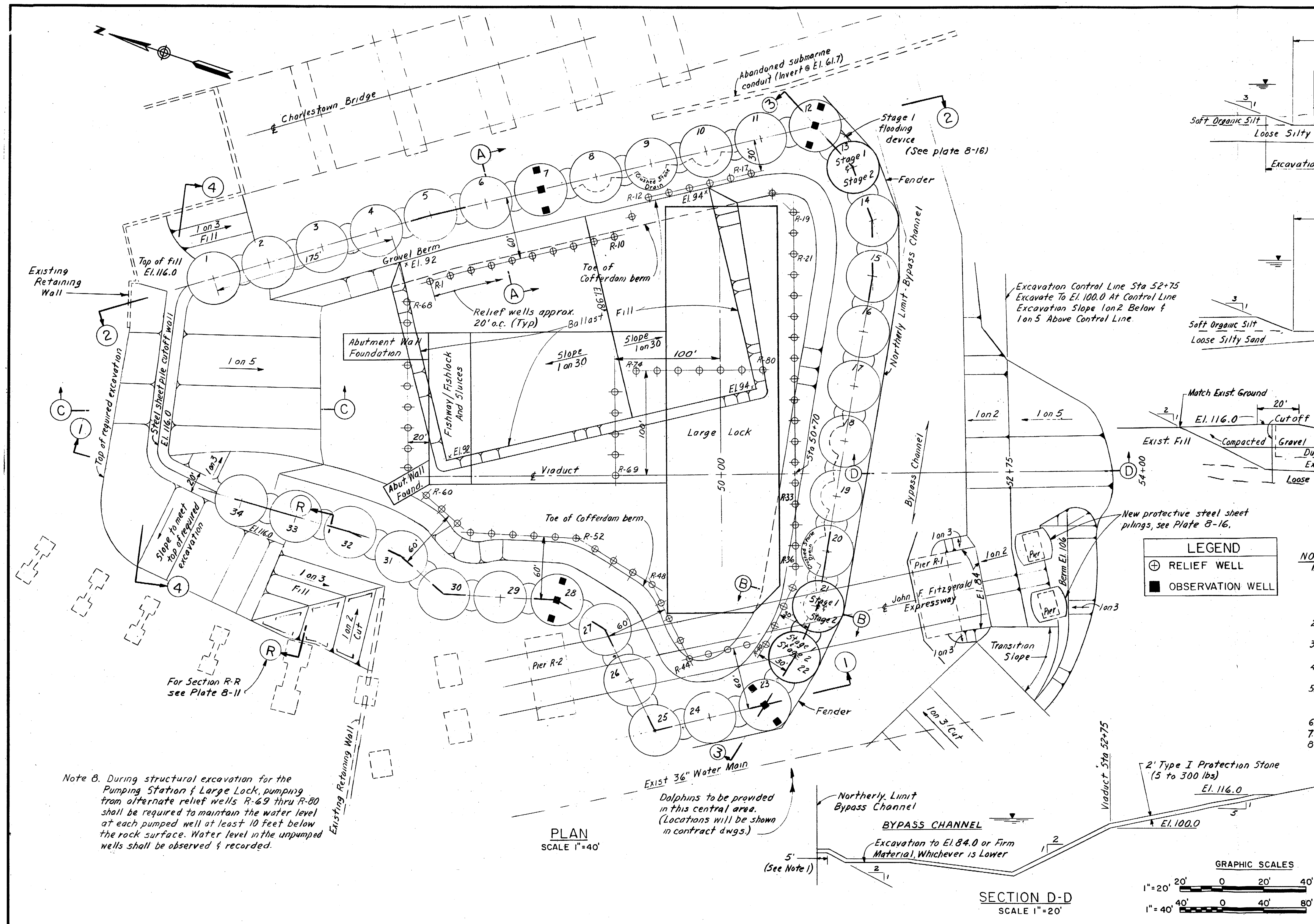
S-6. COST ESTIMATE. The supplemental cost estimate is shown in Table 2. Part A of the estimate is for construction by floating plant method and Part B by the unwatered area method. The cost estimate indicates that relief well construction inside unwatered cofferdam areas will be about $150,000 cheaper than construction from floating plant.

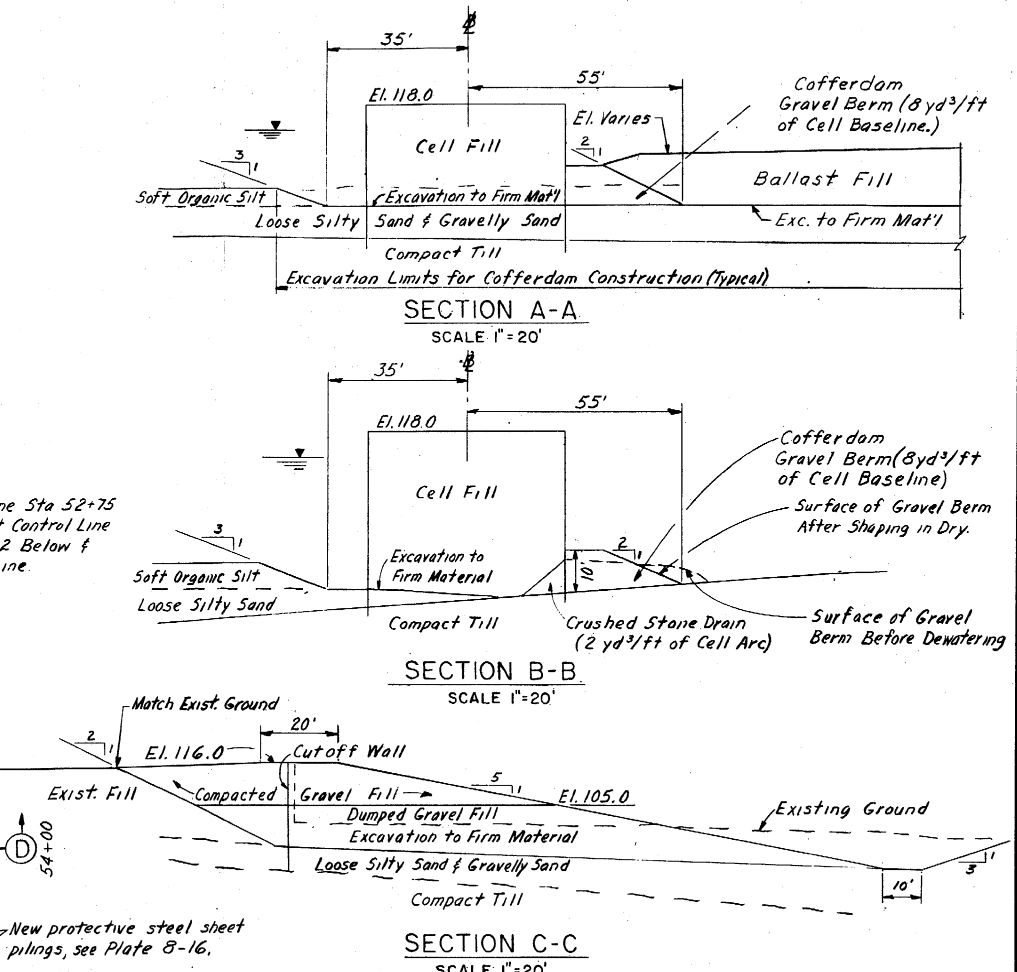
TABLE 2

SUPPLEMENTAL COST ESTIMATE

Description	Quantity	Unit	Unit Price	Estimated Cost
A. Floating Plant Method				
1. Stage 1 Cofferdam				
Relief Wells	74	ea	$3575*	$264,550
Piezometers	6	ea	6700*	40,200
2. Stage 2 Cofferdam				
Relief Wells	24	ea	3575*	85,800
Piezometers	3	ea	4100*	12,300
Subtotal				402,850
Contingency				44,350
			TOTAL	$447,200
B. Unwatered Area Method				
1. Stage 1 Cofferdam				
Relief Wells	80	ea	1170	93,600
Ballast Fill	20,000	cy	5.90	118,000
2. Stage 2 Cofferdam				
Relief Wells	22	ea	1170	25,740
Ballast Fill	5,000	cy	5.90	29,500
Subtotal				266,840
Contingency				29,360
			TOTAL	$296,200

*Reflects corrected unit prices to include full floating plant charges.





NOTES:

1. Bottom of Bypass Channel will be excavated to El. 84.0 or to firm material whichever is lower except not lower than El. 84.0 between Fitzgerald Expressway Pier R-1 & the new protective steel sheet piling & not lower than top of firm material within 5 feet of Northerly Limit of Bypass Channel.
2. Install new protective steel sheet piling prior to excavation of Bypass Channel.
3. Bypass Channel Bottom & side slopes to be protected with 2 foot layer of Type I Protection Stone.
4. See plate 8-10 for notes & details on Relief Wells, Piezometers & Observation Wells. Extend risers pipes of R-33, R-34, R-35 & R-36 prior to flooding stage 1.
5. Excavation limits are those required for construction of cofferdam only. Limits shown are for cofferdam cost estimating purpose and do not include any other required excavations.
6. Soil profiles 1-1 & 2-2 shown on Plate 8-7
7. Soil profiles 3-3 & 4-4 shown on Plate 8-8.
8. Note 8 shown elsewhere on this plate.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DR. BY RDP

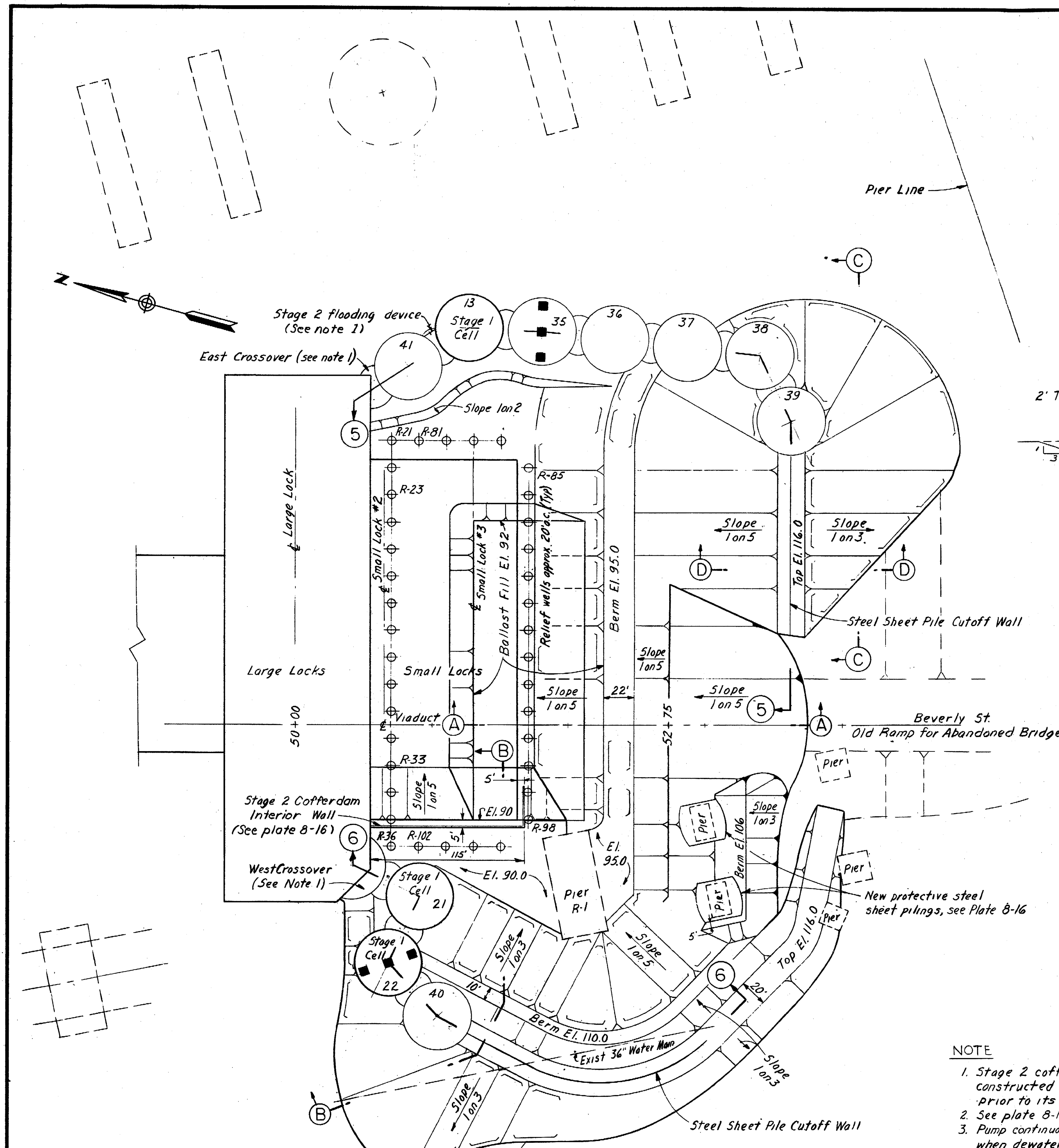
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STAGE I COFFERDAM

CHARLES RIVER BASIN MASSACHUSETTS

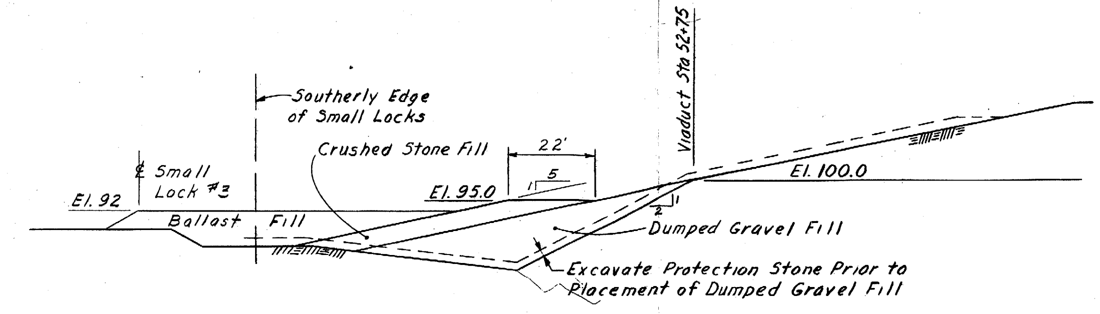
SCALE AS SHOWN

(Supersedes Plate 8-4)

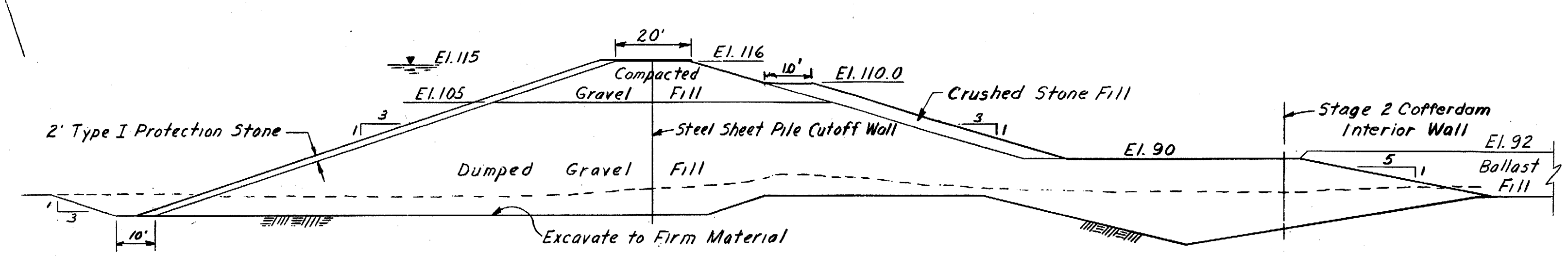
PLATE 8-17



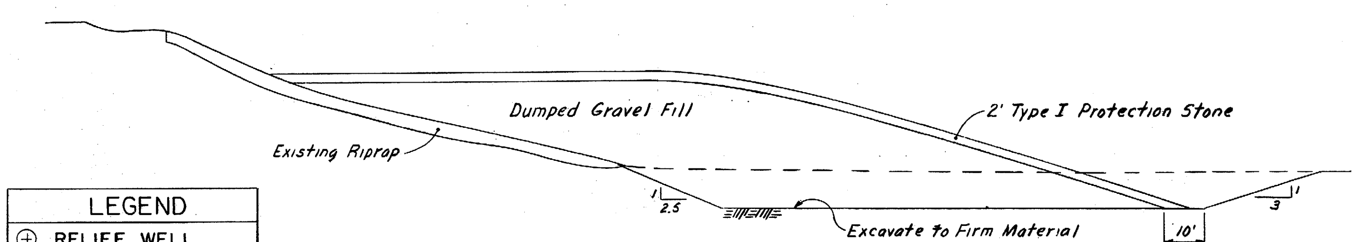
PLAN
SCALE 1"=40'



SECTION A-A
SCALE 1"=20'



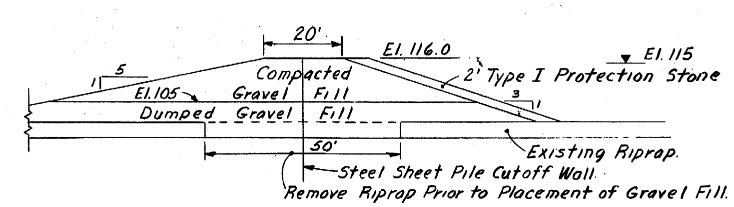
SECTION B-B
SCALE 1"=20'



SECTION C-C
SCALE 1"=20'

LEGEND
⊕ RELIEF WELL
■ OBSERVATION WELL

Note 5. During structural excavation for the Large Lock, pumping from alternate relief wells R-26 thru R-32 shall be required to maintain the water level at each pumped well at least 10 feet below the rock surface. Water level in the unpumped well shall be observed and recorded.



SECTION D-D
SCALE 1"=20'

GRAPHIC SCALES

1"=20' 20' 0 20' 40'

1"=40' 40' 0 40' 80'

NOTE

1. Stage 2 cofferdam connections, crossovers & interior fills shall be constructed to the extent possible inside stage 1 cofferdam prior to its flooding. See Plates 8-15 and 8-16.
2. See plate 8-10 for notes and details on relief wells, and observation wells.
3. Pump continuously from wells R36, R97, R98, R99, R100, R101 and R102. when dewatering is below elev. of fill at well. Maintain water level in well 12' below top of fill at well. Have 2 stand-by pumps. Extend riser pipe of R33, R34, R35 & R36 prior to flooding stage 1, cofferdam
4. Soil profiles 5-5 and 6-6 are shown on Plate 8-9.
5. Note 5 shown elsewhere on this plate

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY

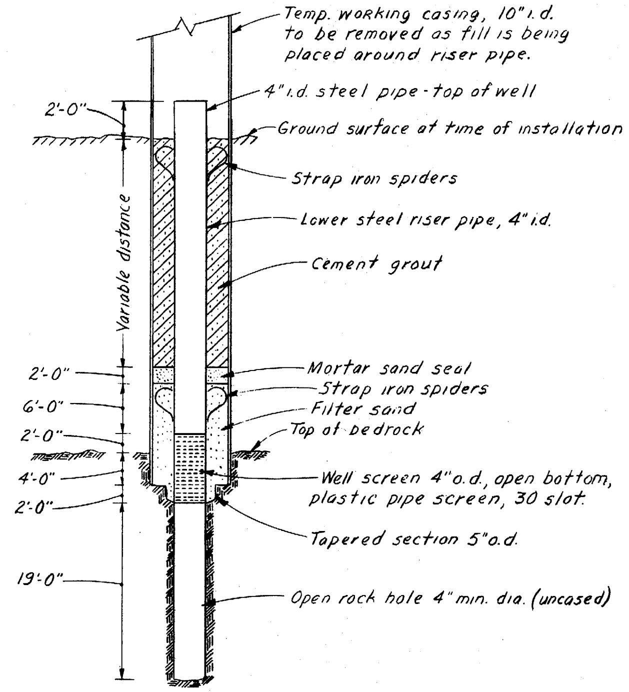
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STAGE 2 COFFERDAM

CHARLES RIVER BASIN MASSACHUSETTS

SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH
APPROVED
CHIEF ENGINEERING DIVISION
DATE
SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

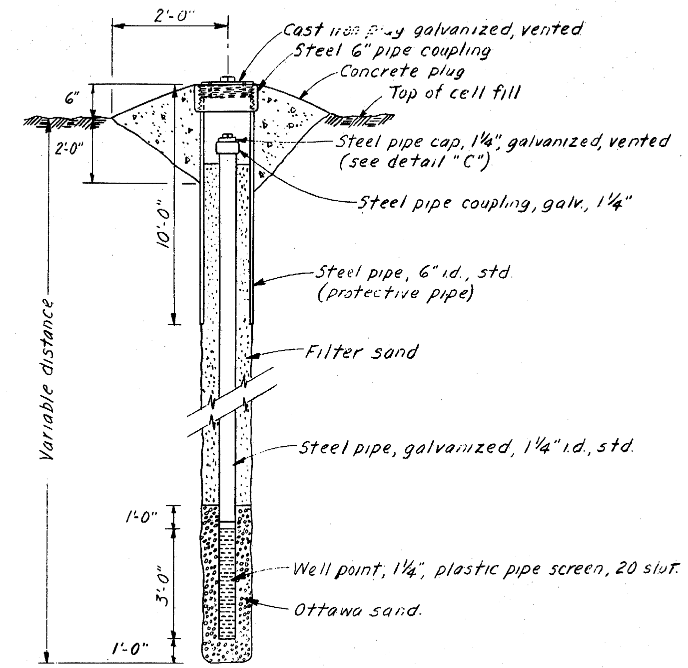
(Supersedes Plate 8-5)

NOTES:
1. Location of relief wells & observation wells are shown on Plates 8-17 & 8-18.



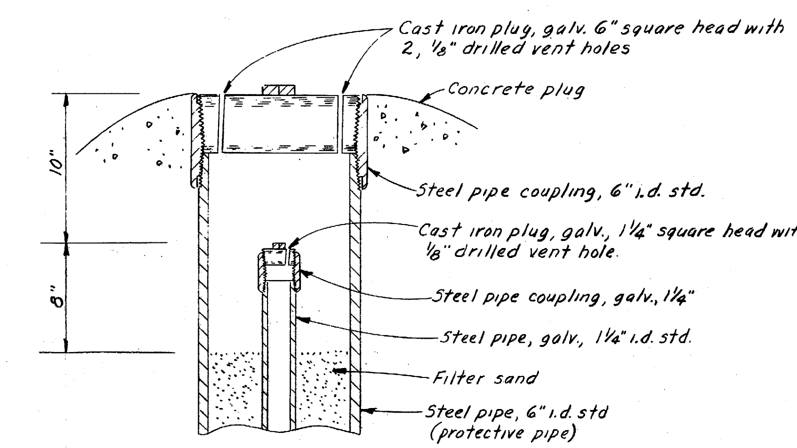
RELIEF WELL

NOT TO SCALE



OBSERVATION WELL

NOT TO SCALE



OBSERVATION WELL

DETAIL "C"

NOT TO SCALE

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

RELIEF WELLS-OBSERVATION WELLS

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

CHIEF ENGINEERING DIVISION

SCALE: NONE | SPEC. NO.

DRAWING NUMBER

SHEET

(Supersedes Plate 8-10)

PLATE 8-19

Prog Des.

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

IN REPLY REFER TO:

NEDED-E

14 February 1973

SUBJECT: Charles River Dam, Boston, Massachusetts, DM No. 8, Cofferdams

HQDA (DAEN-CWE-B)
WASH DC 20314

1. Transmitted herewith are three copies of Supplement No. 2 to Design Memorandum No. 8, Cofferdams, Charles River Dam, Boston, Massachusetts.

2. This supplement has been prepared to incorporate revisions required to permit simplified installation of Stage II crossover closures, to eliminate Stage II flooding device, and to relocate Stage I flooding device to eliminate tremie concrete.

FOR THE DIVISION ENGINEER:

Incl
as (in trip)

JOHN Wm. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAMS

SUPPLEMENT NO. 2

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASSACHUSETTS

FEBRUARY 1973

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

SUPPLEMENT NO. 2 TO DESIGN MEMORANDUM NO. 8, COFFERDAMS

S2-1. PURPOSE. The purpose of this supplement is to present design revisions which are necessary to permit simplified installation of Stage II crossover closures, to relocate Stage I flooding device to eliminate tremie concrete, and to eliminate Stage II flooding device.

S2-2. SCOPE. This supplement contains revised layout and details of the east and west crossovers, revised layout and details of Stage I flooding device, elimination of Stage II flooding device, and revised cost estimate.

S2-3. EAST AND WEST CROSSOVER.

a. To facilitate these closures a pressure type, self-sealing arrangement of cells is provided to eliminate embedded items in lock walls and to simplify erection of a positive closure. This is accomplished by attaching a 234° degree segment of a 25 foot diameter piggyback cell to the main 50 ft. diameter cell and a timber block full length at contact point of cell and lock wall.

b. Two pressure characteristics provide closure; first, the timber is inserted between the concrete lock wall and unfilled cells, the cell diameter expands upon filling thus clamping timber against lock wall. Secondly, the piggyback cell is located such that exterior water pressure deflects the cell into timber and lock wall.

c. Cell Expansion. Each sheet piling has slack in fingers which averages 3/8" in 15-1/4" width of sheet, thus 37 sheets in piggyback can expand the circular arc by 13-7/8" when filled and increases the diameter by 4.4".

d. This procedure has been used successfully by the Huntington District.

S2-4. RELOCATION OF STAGE I FLOODING DEVICE. Relocation of flooding device from till El. 75± to till El. 90± will eliminate the requirement for tremie concrete below the flooding bulkhead. The space between cells No. 29 and No. 30 provides till contours favorable to this condition and will be utilized to simplify construction.

S2-5. ELIMINATION OF STAGE II FLOODING DEVICE. Facilities constructed in Stage I provide adequate control of water for Stage II flooding. The north channel wall of Small Lock No. 2 with filling culvert and ports is built in Stage I construction; control is provided by stoplogs in the filling culverts. The stoplogs must be in place since the culvert is open to the water and below the water surface. Therefore, the Stage II flooding device is eliminated to remove the redundancy of control and to simplify construction.

S2-6. COST ESTIMATE. The supplemental cost estimate is shown in Table 3. Part A represents costs related to original Design Memorandum No. 8 - Cofferdams. Part B represents costs related to Supplement No. 2. The supplemental cost estimate indicates that the provisions of Supplement No. 2 will reduce the original estimate by $70,000.

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

SUPPLEMENT NO. 2 TO DESIGN MEMORANDUM NO. 8

COFFERDAMS

CONTENTS

LIST OF TABLES

LIST OF PLATES

TABLE 3

SUPPLEMENTAL COST ESTIMATE

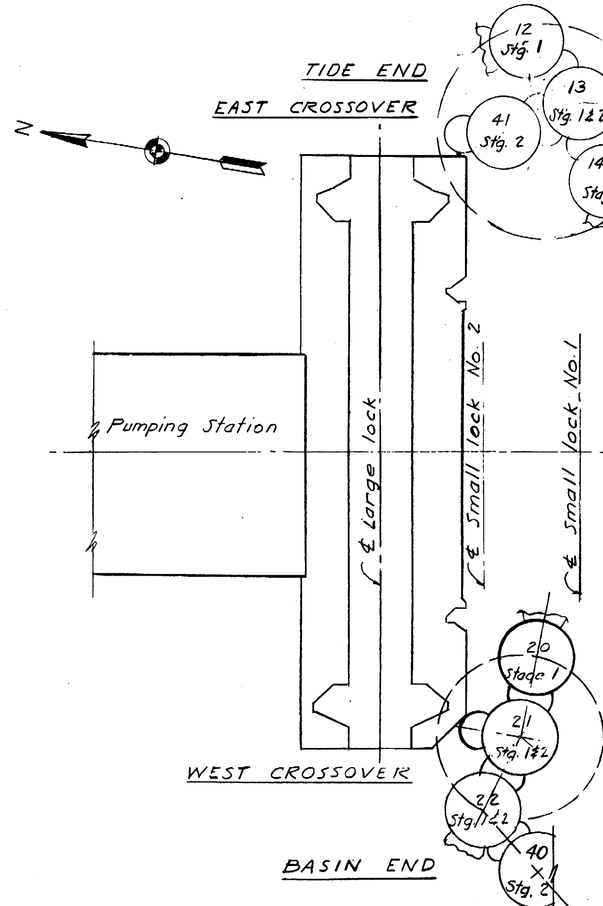
	Description	Quantity	Unit	Estimated Cost
A.	Original Scheme			
	1. East & West Crossover Steel Sheet Piling and Misc.	140	tons	$ 82,000
	2. Flooding Device	14	tons	29,100
	3. Tremie Concrete	255	cy	16,200
			TOTAL	$127,300
B.	Supplement No. 2 Scheme			
	1. East & West Crossover (Piggy-back Cells) Steel Sheet Piling	98	tons	$ 43,000
	2. Flooding Device	7	tons	14,300
			TOTAL	$ 57,300

C. Comparison

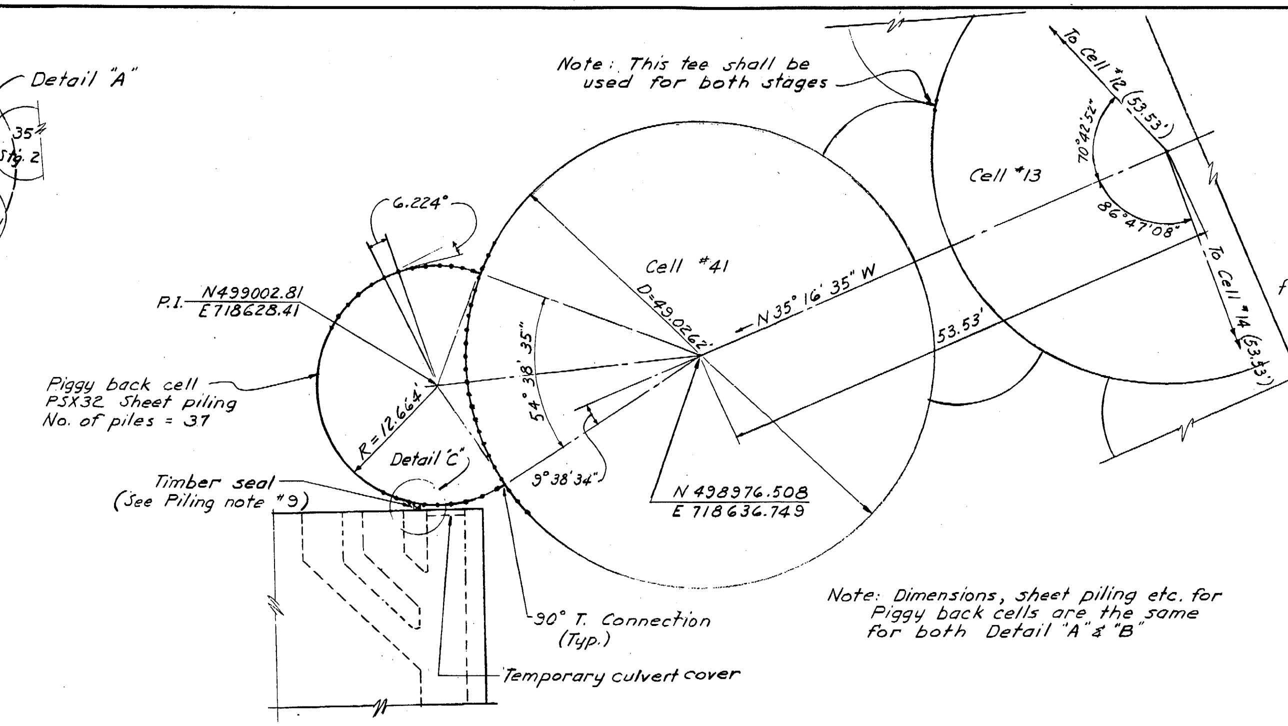
1. All pricing includes overhead, profit, labor benefits and insurance.

2. Total credit for redesign of crossover, less one flooding device and no tremie concrete.

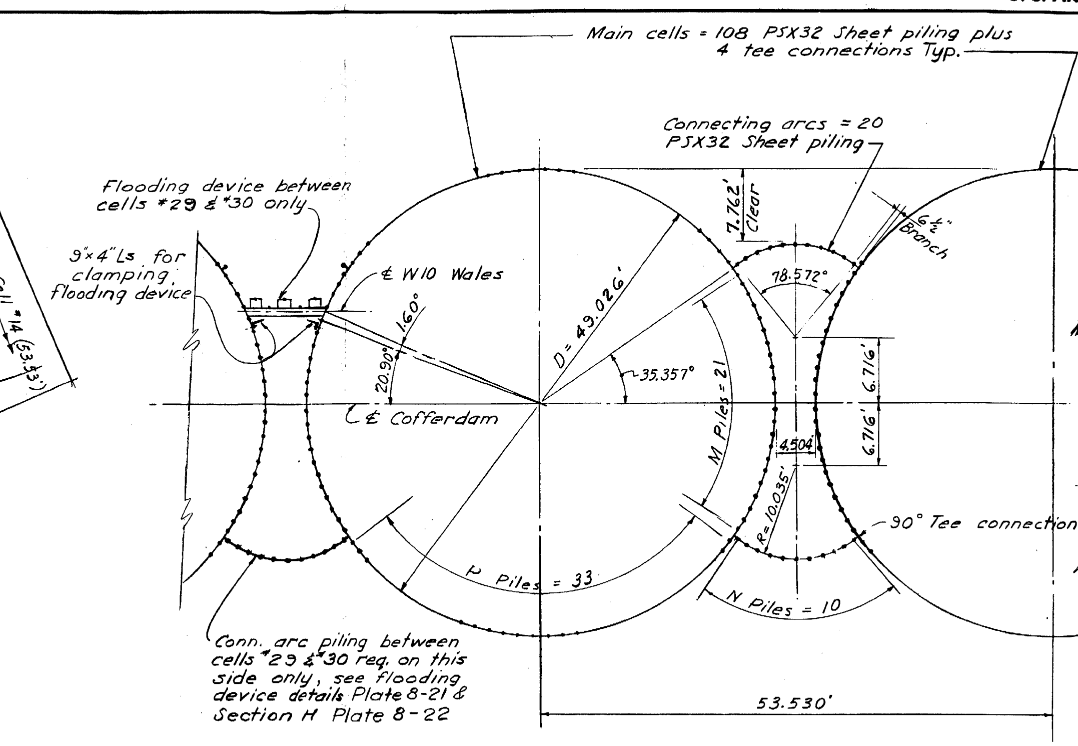
	A	=	$127,300
	B	=	57,300
TOTAL CREDIT	C	=	$ 70,000



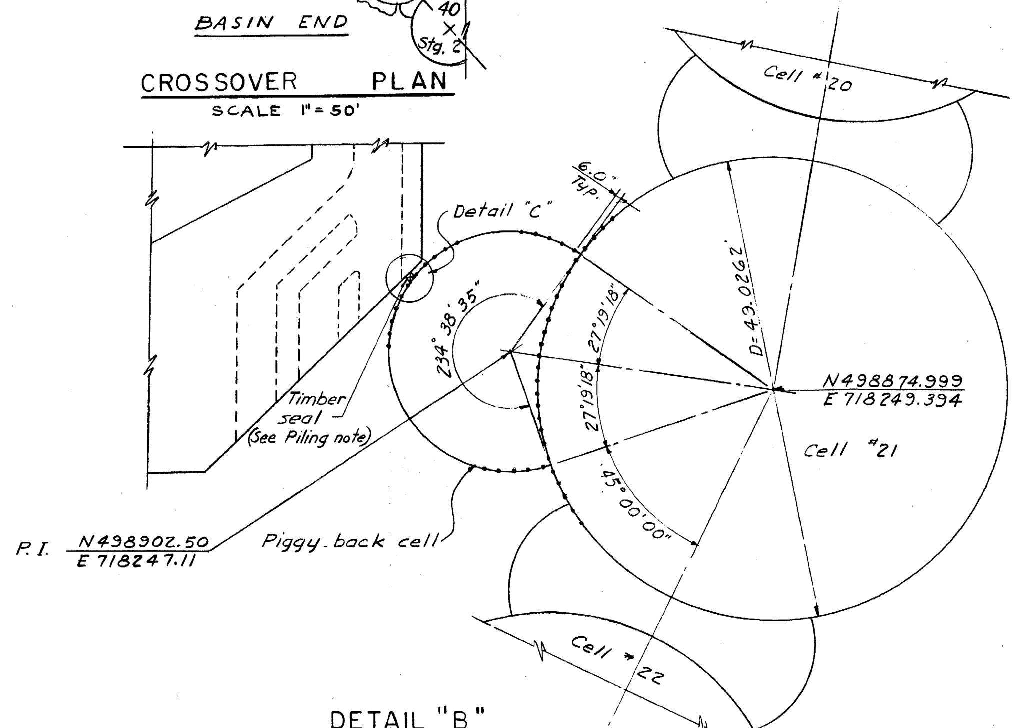
CROSSOVER PLAN
SCALE 1" = 50'



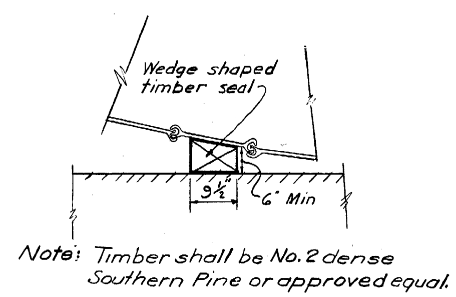
DETAIL "A"
SCALE 1/8" = 1'-0"



TYPICAL COFFERDAM PLAN
SCALE 1/8" = 1'-0"



DETAIL "B"
SCALE 1/8" = 1'-0"



Note: Timber shall be No. 2 dense Southern Pine or approved equal.

DETAIL "C"
SCALE 3/4" = 1'-0"

PILING NOTES

1. Piling for cofferdam cells including connecting arcs, piggy back cells and special fabricated sections shall be Type PSX-32 conforming to ASTM A572-70a.
2. Protective piling around highway piers shall be Type PS-32 conforming to ASTM A328-70.
3. Piling for flooding device shall be Type PZ-38 conforming to ASTM A328-70.
4. For layout of cofferdam cells and stages, see Plates 8-4 & 8-5
5. For sequence of construction, working limitations and placing of berms will be covered in the specifications
6. The bottom elevation of the flooding device is to be determined in the field before shop fabrication. For details see Plate 8-21
7. Structural steel for flooding device shall conform to ASTM A36.
8. Steel soldier piles for Stage 2 interior wall shall conform to ASTM A588 grade A or B (Fy = 50.0 k.s.i. min.) or A572 (Fy = 50.0 k.s.i. min.)
9. Timber seals for full height of cells shall be wedge shaped and placed as shown after piles are driven and before cells are filled.
10. Cell #41 and the two piggy back cells shall be constructed and filled as specified in the dry after large locks are built within Stage I cofferdam.

GRAPHIC SCALES

SAFETY PAYS

VALUE ENGINEERING PAYS DIVIDENDS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY

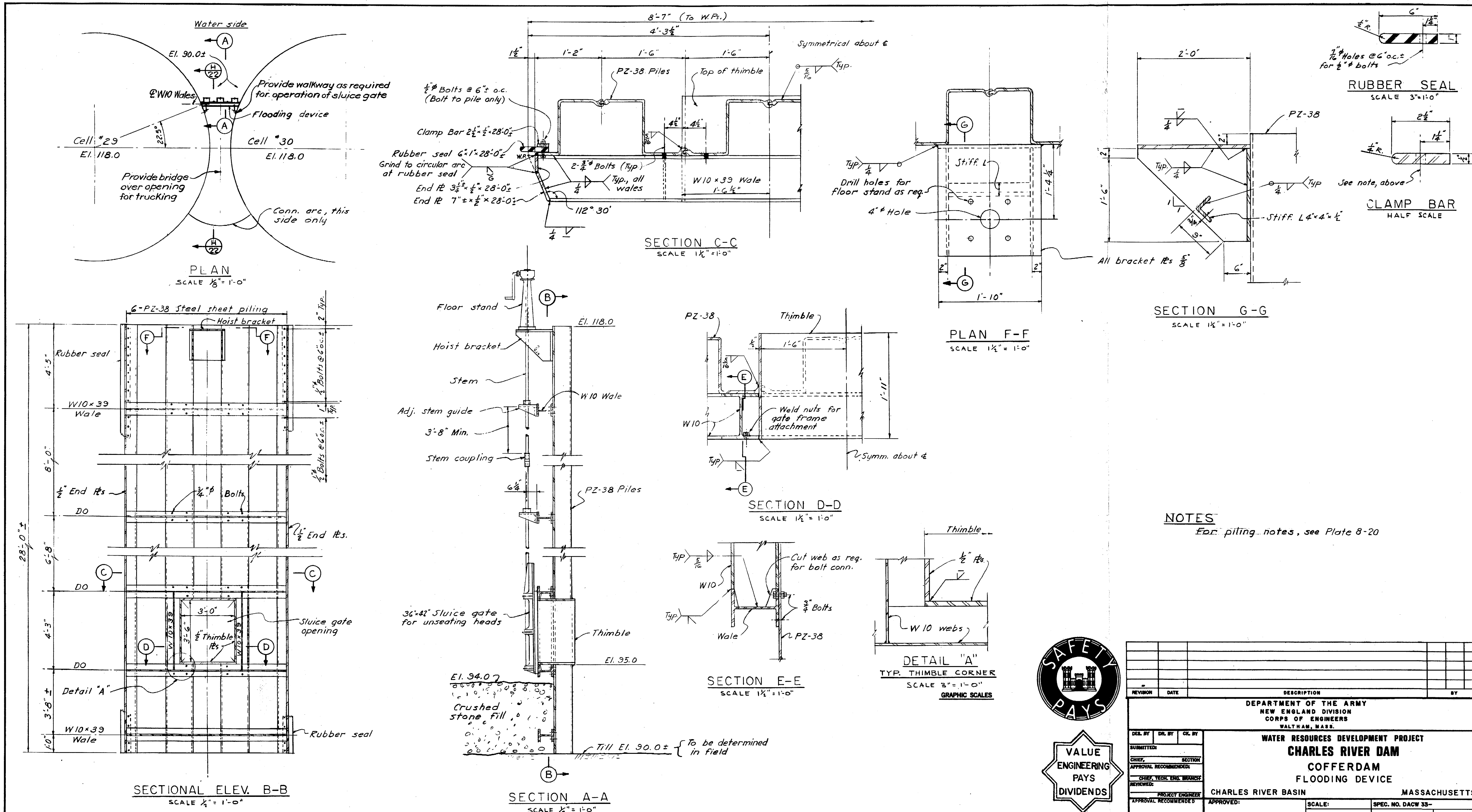
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, BRANCH

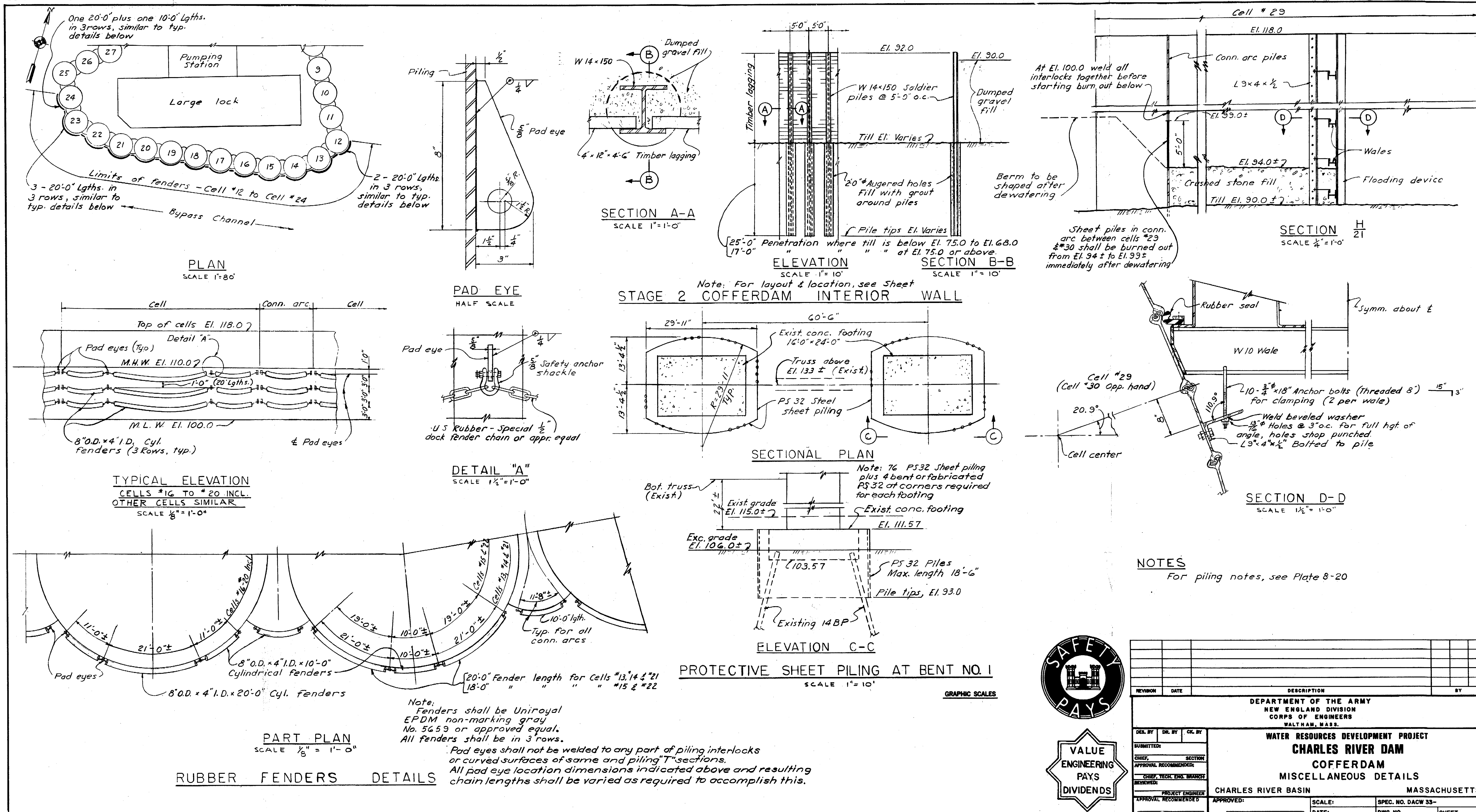
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
COFFERDAM
PLANS AND DETAILS

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED:	SCALE:	SPEC. NO. DACW 33-	
CHIEF, ENGINEERING DIVISION	DATE:	DWG. NO.	SHEET

(SUPERSEDES PLATE 8-15)


PLAN
SCALE 1/8" = 1'-0"
SECTION C-C
SCALE 1 1/2" = 1'-0"
PLAN F-F
SCALE 1 1/2" = 1'-0"
SECTION G-G
SCALE 1 1/2" = 1'-0"
RUBBER SEAL
SCALE 3" = 1'-0"
CLAMP BAR
HALF SCALE
SECTIONAL ELEV. B-B
SCALE 1/4" = 1'-0"
SECTION A-A
SCALE 1/4" = 1'-0"
SECTION D-D
SCALE 1 1/2" = 1'-0"
SECTION E-E
SCALE 1 1/2" = 1'-0"
DETAIL "A"
TYP. THIMBLE CORNER
SCALE 3" = 1'-0"
GRAPHIC SCALES
NOTES
For piling notes, see Plate 8-20
Provide walkway as required for operation of sluice gate
Flooding device
Provide bridge over opening for trucking
Conn. arc, this side only
Cell #29
Cell #30
El. 118.0
Water side
Floor stand
Hoist bracket
Stem
Adj. stem guide
Stem coupling
36"-42" Sluice gate for unseating heads
Thimble
PZ-38 Piles
W10 Wale
Crushed stone fill
Till El. 90.0± To be determined in field
6-PZ-38 Steel sheet piling
Rubber seal
W10×39 Wale
Sluice gate opening
Detail "A"
SAFETY PAYS
VALUE ENGINEERING PAYS DIVIDENDS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
COFFERDAM
FLOODING DEVICE
CHARLES RIVER BASIN
MASSACHUSETTS
SPEC. NO. DACW 33-



One 20'-0" plus one 10'-0" Lgths. in 3 rows, similar to typ. details below
Pumping Station
Large lock
Limits of fenders - Cell #12 to Cell #24
3 - 20'-0" Lgths. in 3 rows, similar to typ. details below
Bypass Channel
2 - 20'-0" Lgths. in 3 rows, similar to typ. details below
PLAN
SCALE 1"=80'
Piling
Pad eye
PAD EYE
HALF SCALE
W 14 x 150
Dumped gravel fill
4" x 12" x 4'-6" Timber lagging
SECTION A-A
SCALE 1"=1'-0"
Timber lagging
El. 92.0
W 14x150 Soldier piles @ 5'-0" o.c.
Till El. Varies
20"ø Augered holes Fill with grout around piles
Pile tips El. Varies
25'-0" Penetration where till is below El. 75.0 to El. 68.0
17'-0" " " " " at El. 75.0 or above.
ELEVATION
SCALE 1"= 10'
El. 90.0
Dumped gravel fill
SECTION B-B
SCALE 1"= 10'
Note: For layout & location, see Sheet
STAGE 2 COFFERDAM INTERIOR WALL
Cell #29
El. 118.0
Conn. arc piles
At El. 100.0 weld all interlocks together before starting burn out below
L 9 x 4 x 1/2
El. 99.0±
El. 94.0±
Wales
Crushed stone fill
Flooding device
Till El. 90.0±
Berm to be shaped after dewatering
Sheet piles in conn. arc between cells #29 & #30 shall be burned out from El. 94± to El. 99± immediately after dewatering
SECTION H/21
SCALE 1/4"=1'-0"
Cell
Conn. arc
Cell
Top of cells El. 118.0
Detail "A"
Pad eyes (Typ.)
M.H.W. El. 110.0
1'-0" (20' Lgths.)
M.L.W. El. 100.0
8" O.D. x 4" I.D. Cyl. fenders (3 Rows, typ.)
℄ Pad eyes
TYPICAL ELEVATION
CELLS #16 TO #20 INCL.
OTHER CELLS SIMILAR
SCALE 1/8"=1'-0"
Pad eye
5/8" Safety anchor shackle
U.S. Rubber - Special 1/2" dock fender chain or appr. equal
DETAIL "A"
SCALE 1 1/2"=1'-0"
60'-6"
29'-11"
Exist. conc. footing 16'-0" x 24'-0"
Truss above El. 133± (Exist.)
R=29'-11" Typ.
PS 32 Steel sheet piling
SECTIONAL PLAN
Bot. truss (Exist.)
Note: 76 PS32 Sheet piling plus 4 bent or fabricated PS32 at corners required for each footing
Exist. grade El. 115.0±
Exist. conc. footing
El. 111.57
Exc. grade El. 106.0±
103.57
PS 32 Piles Max. length 18'-6"
Pile tips, El. 93.0
Existing 14BP
ELEVATION C-C
PROTECTIVE SHEET PILING AT BENT NO. 1
SCALE 1"= 10'
GRAPHIC SCALES
Rubber seal
Symm. about ℄
W 10 Wale
Cell #29 (Cell #30 Opp. hand)
20.9°
Cell center
10 - 3/4"ø x 18" Anchor bolts (Threaded 8") for clamping (2 per wale)
Weld beveled washer
13/16"ø Holes @ 3" o.c. for full hgt. of angle, holes shop punched.
L 9" x 4" x 1/2" Bolted to pile
SECTION D-D
SCALE 1 1/2"= 1'-0"
NOTES
For piling notes, see Plate 8-20
Cells #16 to #20 Incl.
Cells #15 & #22
Cells #13, #14 & #21
11'-0"±
21'-0"±
19'-0"±
10'-0"±
11'-8"±
10'-0" lgth.
Typ. for all conn. arcs
Pad eyes
8" O.D. x 4" I.D. x 10'-0" Cylindrical fenders
8" O.D. x 4" I.D. x 20'-0" Cyl. fenders
20'-0" Fender length for Cells #13, 14 & 21
18'-0" " " " " #15 & #22
PART PLAN
SCALE 1/8" = 1'-0"
RUBBER FENDERS DETAILS
Note:
Fenders shall be Uniroyal EPDM non-marking gray No. 5659 or approved equal.
All fenders shall be in 3 rows.
Pad eyes shall not be welded to any part of piling interlocks or curved surfaces of same and piling "T" sections.
All pad eye location dimensions indicated above and resulting chain lengths shall be varied as required to accomplish this.
SAFETY PAYS
VALUE ENGINEERING PAYS DIVIDENDS
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
COFFERDAM
MISCELLANEOUS DETAILS
CHARLES RIVER BASIN MASSACHUSETTS
SCALE:
DATE:
SPEC. NO. DACW 33-
DWG. NO.
SHEET
APPROVED:
CHIEF, ENGINEERING DIVISION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

IN REPLY REFER TO:

NEDED-E

8 June 1972

SUBJECT: Charles River Dam, Boston, Massachusetts, DM No. 8, Cofferdams

HQDA (DAEN-CWE-B)
WASH DC 20314

In accordance with ER 1110-2-1150, there is submitted for review and approval DM No. 8, Cofferdams, for the Charles River Dam Project.

FOR THE DIVISION ENGINEER:

JOHN Wm. LESLIE
Chief, Engineering Division

Incl (10 cys)
as

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM
CHARLES RIVER BASIN
MASSACHUSETTS

Design Memoranda Index

No.	Title	Anticipated Submission Date	Date Submitted	Date Approved
1	Hydrology and Tidal Hydraulics		21 May 71	2 Aug 71
2	General Design, Site Geology and Relocations		14 Feb 72	13 Mar 72
3	Concrete Materials		19 Feb 71	29 Mar 71
4	Embankments and Foundations		22 Feb 72	15 Mar 72
5	Pumping Station		13 Mar 72	
6	Vehicular Viaduct		28 Feb 72	15 Mar 72
7	Navigation Locks and Facilities		20 Mar 72	
8	Cofferdams		8 June 72	

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAMS

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASSACHUSETTS

JUNE 1972

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAMS

LIST OF PLATES

LIST OF TABLES

APPENDIX

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN

MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

COFFERDAM

A. PERTINENT DATA

Elevation Control

Datum	Metropolitan District Commission Datum (M.D.C.)
Equation	105.65 ft. M.D.C. = 0.0 m.s.l.

Tides, Boston Harbor

Mean High Water	110.2
Mean Low Water	100.8

Upstream Pool

Normal Basin	El. 108.0

Downstream Pool

Tidal, elevation varies

Bypass Channel Design Requirements

Navigation:

Minimum Width	45 feet
Channel Bottom	El. 86.0

Flood Flow:

20- year frequency	10,000 c.f.s.

Selected Cofferdam Design Data

Water Level	Max. El. 115.0
Top of Cofferdam - Earth Dike	El. 116.0
Top of Cofferdam - Steel Sheet Pile Cell	El. 118.0
Cell Diameter	49.026 ft

Number of Circular Cells

Stage 1	34*
Stage 2	10

*3 Cells Re-Used for Stage 2

B. INTRODUCTION

1. PURPOSE. The purpose of this memorandum is to present design analyses of construction cofferdams in accordance with ETL 1110-2-134, dated 5 November 1971.

2. SCOPE. This memorandum covers design analyses for Stage 1 and 2 Cofferdams, Cofferdam Crossover structures, interior walls, earth-dike cofferdams, earth slopes, excavations, fills and pressure relief wells in the bedrock.

3. DESCRIPTION OF SITE. The cofferdams will be constructed in two stages across the Charles River. At the project site, the river is about 500 feet wide and not deeper than about 25 feet below mean sea level; the deepest portion occurs within the existing navigation channel along the south bank of the river.

Present day riverbanks evolved out of gradual encroachment of the river channel by commercial waterfront development work and construction of bridge approach ramps. The major part of the area is clustered with ruins of an old bridge, fender piles, bulkheads, piers, utility lines,and debris of simlar abandoned structures.

C. DESIGN CRITERIA

4. ENGINEERING MANUAL.

a. EM 1110-2-2906, Design of Pile Structures and Foundations.

b. Draft of above EM dated 1 February 71. (See EC 1110-2-114).

c. EM 1110-2-1902, Stability of Earth and Rock-Fill Dams.

d. EM 1110-2-2300, Earth and Rock-Fill Dams - General Design and Construction Considerations.

e. EM 1110-2-1908, Instrumentation of Earth and Rock-Fill Dams.

f. EM 1110-1-2101, Working Stresses for Structural Design.

g. EM 1110-2-2502, Retaining Walls.

5. ENGINEER TECHNICAL LETTERS.

a. ETL 1110-2-134, Construction Cofferdams.

b. ETL 1110-2-43, Steel Sheet Piling.

c. ETL 65-12, Design of Sheet Pile Cellular Cofferdam Connections.

D. PROPOSED RIVER STRUCTURES

6. DESCRIPTION. The river concrete structures are made up of five components as shown in Plates 1 and 2. From north to south they are (a) the fish passage and sluicing facilities, (b) the pumping station, (c) the large lock, (d) the small lock No. 2 and (e) the small lock No. 1. The highway viaduct will be constructed over the entire river structures. Normal river flow will pass through the sluicing facilities. During flood conditions, the river flow will be pumped to the ocean side of the barrier through the pump station.

7. CONSTRUCTION SEQUENCE RESTRAINTS. A restraint to the construction sequence is imposed by the requirement that a construction opening must be provided for navigation and for passage of flood flows. The proposed bypass channel satisfies both flood passage and navigation requirements. The bypass channel has to remain operational until the large lock and the sluicing facilities are completed.

E. HYDRAULICS AND NAVIGATION

8. GENERAL. The construction of the first phase of the new Charles River dam will require cofferdams across the Charles River. These cofferdams must be adequate in height to prevent undue risk of overtopping and the bypass channel must be sufficient in size for the passage of both normal and floodflows as well as navigation. Design of the cofferdams and bypass channel involved hydraulic analysis of both tidal data for the harbor and normal and maximum flow conditions in the river.

9. TIDES. Maximum stages at the project site will result from abnormally high tides. High tides can occur in Boston Harbor during the fall season as a result of hurricanes, or during any season of the year as the result of severe low pressure weather systems, referred to as "northeasters," moving up the coast, east of Boston. Though coastal storms can occur any season of the year, in the past they have occurred most frequently during the winter season. Considering the 20 highest tides of record in Boston, it is found that 17 such tides, or 85 percent, occurred during the six month period, November through April, and only 3 or 15 percent, during May through October with none in June and July. Pertinent data on tides at Boston are as follows:

Mean Tide Range	9.5 ft.
Spring Tide Range	13.0 ft.
Mean High Water	110.25 MDC
Mean Low Water	100.8 MDC
Average Spring High Water	110.9 MDC
Record High Water	
April 14, 1851	115.7 MDC
(Adjusted*)	116.6 MDC
10 Year Freq. Tide	114.2 MDC
20 Year Freq. Tide	115.2 MDC
50 Year Freq. Tide	115.8 MDC
100 Year Freq. Tide	116.2 MDC

*Adjusted to 1970 for general rise in sea level.

Normal Tide Cycle	12 hours
Normal Max. Rate of Change	2.5 ft./hr.
Normal Period Tide In:	
Upper 1/2 ft. Range	2 hours
Upper 1 ft. Range	2.6 hours
Upper 2 ft. Range	3.7 hours

Elevation 116.0 feet, MDC datum, the adopted minimum cofferdam top elevation, is 0.3 foot above the highest tide ever experienced in Boston, but 0.6 foot below that record tide after adjustment to 1970 for past rise in sea level. This elevation was selected only after comparative studies demonstrated that the small percentage savings in cost of a lower cofferdam height did not justify the added risk of overtopping. Elevation 116.0 MDC is about a once in 80 years frequency tide level, based on adjusted data, and cofferdams at this height will provide a one foot freeboard above a 15-year frequency tide level of 115 feet, MDC.

Wave action at the site during abnormally high tides will not be severe and will be mostly of a "choppy" variety due to lack of effective fetch. Storms producing abnormal tides at Boston generally have winds from the east which will result in the greatest wave action on the downstream cofferdam. The fetch distance from East Boston to the new damsite is less than one mile. This fetch, with an effective overland wind speed of 40 miles per hour, would result in a wave height (crest to trough) of 1.9 feet. High buildings in the area and the Charlestown bridge just downstream serve to further modify the effectiveness of wave producing winds.

10. RIVERFLOWS. Riverflows through the bypass channel will consist of: (a) water sluiced through existing Charles River dam, (b) discharges from marginal-conduit, (c) runoff from intervening two square miles of drainage area, and (d) tidewater from the 40 acres of bay area between the damsites. Tidewater flow is a function of rate of tidal change and would be a normal maximum of 1,200 cfs at mid-tide, and near zero during periods of low and high tide.

The primary source of flow in the river is that sluiced through the present upstream dam. The average flow of the Charles River is about 100 cfs, and since sluicing at the dam is zero during high tide, it can be assumed to approach twice the average or 200 cfs at low tide. Maximum floodflows at the new damsite, while under construction, would be about 10,000 cfs, assuming: (a) a maximum discharge capacity of 1,000 cfs through each of eight 7 x 10.5 foot sluice gates at the existing dam, (b) 1,000 cfs discharge from the marginal conduit, and (c) a runoff rate of 1,000 cfs from the intervening two square mile drainage area.

The bypass channel, shown on plate 8-4 will be approximately 700 feet long and have a minimum cross sectional area below low tide of 1,500 square feet. Because discharges are a maximum at low tide, velocities and head loss in the bypass channel accordingly will be a maximum at low tide and approach zero at high tide. Velocities and head losses through the bypass channel during low tide for various flow rates are listed below:

Downstream Tide Elevation (ft, MDC)	Flow (cfs)	Velocity (ft/sec)	Head Loss 1.5 Hours (ft)	Upstream Elevation (ft, MDC)
100.8	1,000	0.7	0.01	100.8+
100.8	2,000	1.3	0.04	100.8+
100.8	4,000	2.6	0.15	100.9
100.8	6,000	4.0	0.38	101.2
100.8	8,000	5.3	0.66	101.5
100.8	10,000	6.6	1.00	101.8

With normal tidal discharge of 1,200 cfs, average velocities across the channel will be 0.8 foot per second with estimated velocities at the center of the channel about 1.2 to 1.5 feet per second. With maximum floodflows of 10,000 cfs, average low tide velocities will be 6.6 feet per second with estimated maximum velocities of 8 to 10 feet per second at the center of the channel. It is concluded that the bypass channel will be adequate to pass both normal and floodflows, with little restriction to navigation except during periods of maximum flood discharge.

11. COFFERDAM FLOODING DEVICES. Cofferdam flooding devices will be provided for flooding of the cofferdam for either an emergency situation or at completion of required work.

a. Stage 1 Cofferdam. The device will consist of a 36" x 42" gate valve with invert at El. 95.0. The device is capable of flooding the cofferdam area to El. 90 with an outboard average tide at about El. 105, in about 5 to 6 hours.

b. Stage 2 Cofferdam. The device will consist of an 18" x 42" gate valve with invert at El. 95.0. The device is capable of flooding the cofferdam area to El. 90 with an outboard average tide at about El. 105 in about 4 to 5 hours.

12. NAVIGATION.

a. During construction of the large navigation lock and the pump station, estimated to take 2 years to complete, a temporary bypass channel will be required. The channel proposed for this purpose is essentially the present channel which extends from Boston Harbor; through the navigation openings of the Charlestown, Warren Avenue, and Fitzgerald Expressway Bridge, to points upstream. The navigational clearance and the fendering system of the Charlestown Bridge will remain the same. The channel alinement through the bridge will also remain unchanged.

b. The remains of the old Warren Avenue Bridge is to be removed in entirety and the bypass channel area dredged to El. 84 and covered with a 2-foot layer of stone protection. The cellular steel pile Stage 1 Cofferdam will be constructed with its southern limit lying for the most part, along the existing channel as indicated on Plate 8-4. One upstream cell will encroach on the present channel by about 10 feet, but this cell is a short distance upstream of the point of least horizontal navigation clearance, i.e. between the northerly corner of the south abutment of the Fitzgerald Expressway and the southern limit of the proposed Stage 1 Cofferdam. The clearance at this point is about 50 feet. This clearance will not be less than at present. Also the channel alinement will remain essentially the same, and will be improved somewhat because of the proposed dredging which will permit additional maneuvering room.

c. Discussions with a Boston based company which transports fuel by tug-barge systems to terminals within the Charles River Basin, indicate that generally the alinement, depth, and widths of the proposed bypass will be adequate and even in some instances improved. However, representatives of that company point out that under existing conditions substantial difficulty is encountered in turning the tug-barge system to the northwest just as it navigates past the bridge abutment of the Fitzgerald Expressway. The system must be turned as it navigates that point because of the bulkhead located immediately upstream to the west. The one cell mentioned above, which will encroach to some degree on the channel, will add to the navigation difficulty to a moderate degree. It was suggested by the company representatives that a pile cluster, or two of them; provided at or in the vicinity of the upstream end of the cofferdam, would aid greatly as a pivotal point as lines could be tied to these clusters to hold the system in place while maneuvering. The tidal and freshwater runoff currents add to the maneuvering difficulties.

d. Such dolphins will be provided for the purpose mentioned. Also, the existing fendering, which is to be removed along the bridge abutment, will be replaced with temporary fendering for the 2-year period as the tug-barge system bounces along these fenders when turning. The temporary fendering will be removed thereafter. Fender system for Stage 1 Cofferdam is shown on Plate 8-4.

F. FOUNDATION INVESTIGATION

13. GENERAL. Boring locations are shown on Plate 8-2. Boring logs and soil test data are shown on DM No. 4 EMBANKMENTS AND FOUNDATIONS.

Foundation data on John F. Fitzgerald Expressway Bridge piers, the Charlestown Bridge piers, and old Warren Avenue Bridge were obtained and reviewed for the purpose of helping evaluate and corroborate the data obtained specifically for the design of the Charles River Dam project.

G. SELECTION OF COFFERDAM TYPE

14. GENERAL. The cofferdam type shown in this Design Memorandum was developed from the basic circular cell cofferdam concept conceived originally in 1964 by Charles A. Maguire and Associates in their basic planning and engineering studies made for the Metropolitan District Commission, Commonwealth of Massachusetts.

Cofferdam types other than the circular cell type were considered in 1964 and again during the preparation of this memorandum. Other types considered included single wall cofferdam with earth fill and batter pile bracing and braced double wall cofferdams.

The horse-shoe shaped cofferdam of circular cells on three sides and earth dike on the shore side selected for Stage 1 construction is considered the most suitable and economical. It provides ample space for simultaneous construction of the large lock, the pumping station, the fishway and sluicing facilities, abutment wing walls and permanent earth fills.

The selection of cofferdam type for Stage 2 was made on the basis of using the same type of construction selected for Stage 1 although the selection could very well have been braced double wall cofferdams in lieu of cells and earth dikes.

15. LOCATION RESTRAINTS. The cofferdams were located within areas which provided maximum clearances from permanent project structures but yet sufficiently away from existing bridge piers and buried water mains.

On the east side, the cells were located not closer than about 15 feet horizontally from an abandoned submarine conduit which has an invert elevation lower than the anticipated elevation of the cell pile tips.

On the south side of Stage 1 Cofferdam, the cells were located outside of the northerly limit of the temporary bypass channel.

On the west side of Stage 1 Cofferdam, the cells were located at safe distances from a buried water main and several bridge piers. For ease of construction, three cells were located clear of the J.F.

Fitzgerald Expressway Bridge deck so as to eliminate bridge deck interference to pile driving operation.

On the west side of Stage 2 Cofferdam, the cells were located at safe distances from a buried water main and a bridge pier.

16. CONSTRUCTION SEQUENCE. The bypass channel and slope protection plus necessary temporary navigation fenders will be completed prior to complete enclosure of Stage 1 Cofferdam. The Stage 2 Cofferdam will be constructed after the structures in Stage 1 are completed to the extent that the Stage 1 area can be flooded plus the requirement that the large lock is open for navigation purpose and for bypassing the construction period design flood during the Stage 2 construction period.

H. CHARACTERISTICS OF FOUNDATION MATERIALS

17. GENERAL. The characteristics of foundation materials are described to a large extent in Design Memorandum No. 4, EMBANKMENTS AND FOUNDATIONS. The descriptions presented hereinafter are basically oriented toward supplementing the descriptions and data in DM No. 4. The descriptions cover all natural soils and fill material present including materials which are to be removed as part of required foundation treatment.

The foundations areas are typified by the salient delineation of three types of natural soil deposits: organic silt, silty sand and till. Man-made fills overlie natural soils on both shores. The standard penetration resistance value ("N" value) was obtained from borings made prior to 1969. "N" value and penetration resistance data from current borings were used in judging soil compactness and pile driving characteristics.

18. SOIL PROFILES AND SOIL DATA. The locations of borings are shown on Plate 8-2; generalized soil profiles are shown on Plates 8-7 through 8-9; additional soil profiles and soil test data are shown in DM No. 4; contour limes of the surface of the buried natural till feature are shown on Plate 8-6.

19. STAGE 1, COFFERDAM. Generalized soil profiles are shown on Plates 8-7 and 8-8.

a. Easterly Arm. Profile 2-2 on Plate 8-7, shows a generalized soil profile along the easterly arm of the cofferdam. The river bottom elevations vary from about El. 85 to 100, and the entire cofferdam foundation area contains a surficial deposit 5 to 10 feet thick of very soft organic silt.

The organic silt overlies a 2 to 10 foot thick deposit of loose gravelly sand and silty sand (sometimes with sea shells) which, in turn, overlies medium compact to very compact till. In a portion of the foundation reach of cells 9, 10, and 11, the organic silt overlies directly on the till.

The elevation of the surface of the till varies from about El. 70.0 to 90.0. Boring data indicate that the till deposit is generally about 10 to 25 feet thick and it overlies rock. The till consists of medium compact to very compact gravelly sandy silty clay, gravelly sandy clayey silt, gravelly silty clayey sand and gravelly silty sand. The deposit contains cobbles and boulders.

b. Southerly Arm. Profile 3-3 on Plate 8-8, shows a generalized soil profile along the southerly arm of the cofferdam. The river bottom elevations vary from about El. 80 to 100, and the entire cofferdam foundation area contains a surficial deposit 5 to 20 feet thick of very soft organic silt which,in turn, overlies medium compact to very compact till.

The elevation of the surface of the till varies from about El. 70 to 90. Till soil types are described in subparagraph 19a, above. The till deposit is about 20 to 35 feet thick and it overlies bedrock.

c. Westerly Arm. Profile 1-1 on Plate 8-7, shows a generalized soil profile along the westerly arm of the cofferdam. The river bottom elevations vary from about 80 to 100. The river area foundation contains a surficial deposit 5 to 15 feet thick of very soft organic silt which, in turn, overlies medium compact to very compact till. The till is about 10 to 40 feet thick and overlies bedrock. The elevation of the surface of the till varies from about El. 65 to 90. The till soil types are described in subparagraph 19a. In the area of cells 30 to 34, there is a deposit 5 to 20 feet thick of loose to medium compact gravelly silty sand and silty sand with shells sandwiched in between the organic silt and the till. Within the riverbank area, the organic silt is overlain by about 10 to 20 feet of man-made fill consisting of loose to medium compact silty sand, sandy silt, sandy gravel with varying amounts of cinders, bricks, and timber.

d. Northerly Arm. Profile 4-4 on Plate 8-8 shows a generalized soil profile along the northerly arm of the cofferdam. This reach of cofferdam is on man-made land on the Charlestown side of the river and which contains 10 to 20 feet of fill behind river walls. Some of the fill was built on or against timber decks and platforms.

The man-made fill consists principally of loose to medium compact gravelly sand and silty sand interspersed with varying amounts of cinders, masonry waste, wood and organic silty clay. The fill overlies a 5 to 10 foot thick layer of soft organic silt.

The organic silt overlies a 5 to 10 foot thick deposit of loose to medium compact gravelly silty sand and silty sand which, in turn, overlies medium to very compact till. The till surface elevation varies from about El. 80 to 95. The till deposit is 20 to 40 feet thick and it overlies bedrock. The till soil types are described in subparagraph 19a.

e. Standard Penetration Resistance. The values of standard penetration resistance ("N" value) obtained from test borings were used to help judge soil compactness and pile driving characteristics. The data show the following "N" value characteristics.

(1) Till. The "N" value varies generally from 15 to over 90. The "N" value in the top few feet for the easterly reach is, in general, between 15 and 25; and, for the westerly reach, between 25 and 80.

(2) Silty Sand. The "N" value of the silty sand which is sandwiched in between the organic silt and the till varies generally from 5 to 25 and it is generally less than 10 in the river area and occasionally, in limited areas, the value is less than 4.

(3) Man-Made Fill. The "N" value of man-made fill materials vary generally from 5 to 25 but it is occasionally as high as 70.

20. STAGE 2, COFFERDAM. Generalized soil profiles are shown on Plate 8-9.

a. Easterly Arm. The easterly arm of the cofferdam extends from the Large Lock to the Boston shore. Profile 5-5 on Plate 8-9 is a generalized soil profile. The river bottom elevations vary from about 80 to 90 and the river area overburden contains a surficial deposit 5 to 15 feet thick of very soft organic silt.

In general, the organic silt overlies a 5 to 15 foot thick deposit of loose to medium compact gravelly sand and silty sand with shells which, in turn, overlies medium compact to very compact till.

The till deposit is about 10 to 30 feet thick and it overlies bedrock. The elevation of the surface of the till varies from about El. 65 to 85. The soil types in the till deposit are described in subparagraph 19a.

On the Boston shore area, there is man-made fill 25 to 35 feet thick composed essentially of loose to medium compact gravelly silty sand and silty sand inter-mixed with varying amounts of cinders, coal dust and wood. The man-made fill was built on top of the organic silt deposit and has fully consolidated the organic silt.

b. Westerly Arm. The westerly arm of the cofferdam, like the easterly arm, extends from the Large Lock to the Boston Shore. Profile 6-6 on Plate 8-9 is a generalized soil profile. The river bottom is at about El. 80, and the river area overburden contains a surficial deposit of very soft organic silt 5 to 15 feet thick.

The organic silt overlies compact to very compact till except that in the river bank area there is a layer 5 to 15 feet thick of loose to medium compact gravelly sand and silty sand with shells sandwiched in between the organic silt and the till.

The elevation of the surface of the till varies from about El. 65 to 80. The till deposit is about 5 to 30 feet thick and it overlies bedrock. The soil types in the till deposit are described in subparagraph 19a.

On the Boston shore area there is man-made fill and the fill materials are described in subparagraph 20a.

c. Standard Penetration Resistance. "N" values of various soil types are essentially as described in paragraph 19e for the Stage 1 Cofferdam foundation soils.

I. TREATMENT OF RIVER BOTTOM MATERIALS

21. GENERAL. The organic silt in the river bottom is considered unsuitable foundation material and will be removed from within cofferdam foundation areas except on shore areas where it underlies excavation slopes of man-made fills which are to remain. The organic silt will be removed completely from the foundation areas of the sheet pile cellular cofferdams.

Underlying the organic silt there are occasional thin layers of very loose silty sand with shells ("N" value less than 4) which will be removed also.

The lateral extent of removal of river bottom materials are shown on Plates 8-4 and 8-5. The vertical extent of removal will be to the bottom of the organic silt and to the bottom of the aforementioned loose material. Plates 8-7 through 8-9 show the estimated depth of removal by the line denoting the requirement of "excavation to firm material." The contract plans and drawings will provide definite requirements in regards to horizontal and vertical extent of these excavations.

J. STRUCTURAL DESIGN

22. PURPOSE AND SCOPE. This section of the design memorandum presents the design, basic data and assumptions used in the structural design of the cofferdam cells and appurtenant structures. A brief description of the structures with loading conditions is included herein. The structural design including stability investigations of the cell are included in the appendix. The design of the cells on till foundation was made by the same procedures that apply to cells on rock.

23. DESIGN CRITERIA.

a. General. All working stresses conform to those specified in the Engineering Manual EM 1110-1-2101, "Working Stresses for Structural Design" dated 1 Nov 63. Loading conditions, design assumptions and other design criteria are based on the following applicable parts of the Engineering Manual for Civil Works issued by the Office of the Chief of Engineers: "Design of Pile Structures and Foundation (EM 1110-2-2906) as amended by EC 1110-2-114 (same title). Accepted engineering practice is utilized in cases where the Engineering Manuals for Civil Works do not apply.

b. Structural Steel. Steel sheet piling will be PSX32 and conform to ASTM-A-572 Grade 50; Min. yield point stress will be 50,000 psi, basic allowable stress is 30,000 psi (0.60Fy). The interlock strength will be 28,000 pounds per linear inch, but allowable interlock stress will be 14,000 pounds per linear inch (safety factor of 2). Wales and Soldier Piles will conform to ASTM A-36 with minimum yield point at 36,000 psi and have an allowable stress of 20,000 psi (0.55Fy).

c. Timber Lagging for soldier pile construction sheeting will be Douglas Fir, Construction Grade, with allowable f is 1500 psi and horizontal shear (H) is 120 psi which is in accordance with the "National Design Specifications for Stress Grade Lumber and its Fastenings" of the National Lumber Manufacturers Association.

d. Concrete. Not applicable.

e. Reinforcement. Not applicable.

f. Increase in Normal Working Stresses. Not used.

24. BASIC DATA AND ASSUMPTIONS.

a. Controlling Elevations of Cofferdam.

(1)	Top of Cofferdam	El. 116
(2)	Top of Sheet Pile Cells	El. 118
(3)	Maximum Water Surface	El. 115
(4)	Maximum Tailwater (inside cofferdam)	El. 67

b. Controlling Elevations for Stage 2 Interior Wall.

(1)	Top of Sheeting	El. 92
(2)	Top of Saturated Backfill	El. 90
(3)	Minimum Till Surface	El. 68

c. Loads.

(1) Dead Load. The following unit weights for materials are used.

Material	(Unit Weight-lbs./cu.ft) Saturated	Submerged	Friction Angle
Max. Range Cell Fill (Case 1)	134.2	70	30°
Min. Range Cell Fill (Case 2)	119.2	55	30°
Dumped Gravel (Stage 2 Constr. Sheeting)	135.	70	30°
Till (In-situ) Foundation	139.2	75	40°
Sand (In-situ) Foundation	(Same as for Cell Fill)		20°

(2) Live Loads. The following live load is used:

Water taken at 64.2 pounds per cu. ft.

d. External Water Pressure is assumed to act over the entire area in question under the full head available. Uplift is assumed to have the same intensity and shape as indicated by the saturation line except acting in opposite direction.

e. External Earth Pressures are determined in general accordance of the applicable parts of EM 1110-2-2502, "Retaining Walls" and EM 1110-2-2906 with amendments.

f. Earthquake Forces. Not applicable.

g. Ice Pressure. Not applicable.

h. Wind Pressure. Not used.

i. Wave Pressure. Not used.

j. Frost Protection. Not applicable.

25. SHEET PILE CELLULAR CELLS.

a. The cells will utilize PSX32 piling using the standard layout for 50 feet diameter cell and 90° connecting arcs. Since no substantial berm exists on the interior of the cofferdam, extra grade steel (50,000 psi) is required to develop an allowable interlock stress of 14,000 pounds per linear inch. The following minimum safety factors are provided:

(1) Tilting 1.25

(2) Sliding 1.00

(3) Vertical Shear 1.25

b. Closure. Construction procedure requires a 2 stage cofferdam. The first stage is U-shaped assemblage of cells with closure formed on the north side by an earth embankment. The second stage is formed by 2 cellular walls, one on the east and the other on the west side; the south side is closed by an earth embankment and north side is closed by the large lock monolith with embedded sheet pile and exposed interlock to accept closure by connecting arcs of the east and west cellular walls.

c. Weep Drains. Cell drainage will be provided on the inside wall of cells at locations shown on Plate 8-6. The weep holes will be installed as the cofferdam is dewatered and will be constructed by burning a 2 to 3 inch diameter hole which will be enclosed on the outside by a half-round steel basket tack-welded against the face of the sheeting. The basket will be filled with crushed stone as soon as the hole starts to squirt water either after burning or after burning and rodding. This type of weep hole has been used successfully by a local contractor.

d. Loading Conditions. The following loading conditions were investigated in the design of the cells:

(1) Loading Condition No. 1. Water to El. 115, cell fill saturated to El. 118 ocean side to bottom of cell (El 67) on coffered side.

(2) Loading Condition No. 2. Water to El. 115, cell fill saturated to El. 118 ocean side and sloping to El. 94.5 on coffered side.

(3) Loading Condition No. 3. Omitted (no insitu overburden).

(4) Loading Condition No. 4. Water to El. 115, cell fill saturated to El. 118 ocean side and sloping to El. 112 on coffered side.

(5) Extreme Condition. Water to El. 117 in lieu of El. 115 for Loading Condition Nos. 1, 2 and 4 using minimum range (Case 2) cell fill (shown only to indicate extent of reduction of safety factors).

e. Under all conditions of loading, it is found that the cell safety factors are equal to or better than required with the exception of the extreme condition sliding safety factor for Loading Condition No. 4 which is improbable since 100 year design storm is El. 116.2.

K. SLOPE STABILITY

26. GENERAL. The earth cofferdam slopes are 1 on 5 on the inboard side and 1 on 3 on the outboard side except for a short reach in Stage 2, Cofferdam which due to confined space, the slope is 1 on 3 slope above El. 90.0. The 1 on 3 outboard slopes are considered stable based on previous analyses shown on DM 4, EMBANKMENTS AND FOUNDATIONS. The earth dike cofferdam material will be the same type gravelly sand - sandy gravel material specified for the permanent embankment. Slope stability analyses also include analyses of the cut slope on the west side of the Stage 1 Cofferdam on the Charlestown shore, and the cut-fill slope inside the Stage 2 Cofferdam on the Boston shore.

27. EARTH COFFERDAM SLOPES. The inboard earth cofferdam slopes were analyzed for the unwatered condition. Plates 8-12 and 8-13 show the results of analyses. Shear strength parameters and unit weights used in the analyses were selected from DM No. 4 data and

are shown on the aforementioned plates. The crushed stone fill on 1 on 3 inboard cofferdam slope in Stage 2 westerly arm and on the 1 on 5 slopes, was added for slope stability and seepage control purposes.

SECTION ANALYZED	MINIMUM SAFETY FACTOR
Cut-Fill Slope - Boston Shore (Plate 8-12)	1.53
Earth Dike Slope - Stage 2 (Plate 8-13)	1.65

28. CUT-SLOPE CHARLESTOWN SHORE. The outboard cut-slope on the Charlestown shore required for the removal of organic silt in cell foundation area was analyzed for the condition of low tide and fully saturated soil above low tide elevation. (See Plate 8-11). The minimum safety factor thus obtained is 1.44. This analysis is applicable also for the northerly arm of the cofferdam.

L. UNWATERING, PRESSURE RELIEF AND SEEPAGE CONTROL

29. UNWATERING. The water level inboard of the cofferdam will be dropped at a rate of not more than 2 feet per day. This maximum rate of drop is considered a practical rate based on local experience in comparable situations.

The rate of unwatering may affect the rate of drop of the saturation line inside the cells proper and on the hydrostatic pressure in the bedrock in the inboard area. Cell saturation line and uplift pressures in the bedrock will be observed during the unwatering by means of observation wells and piezometers. See Plates 8-4, 8-5, and 8-10 and paragraphs below.

The unwatering rate will be controlled, if necessary, to reduce excess uplift pressures in the bedrock and to control lowering of the saturation line inside the cells.

30. SEEPAGE CONTROL.

a. Earth Portion of Cofferdams. On the Charlestown side of Stage 1, Cofferdam, a steel sheet pile cutoff wall has been provided to control seepage. The cutoff wall extends continuously from the westerly arm of the sheet pile cofferdam to the easterly arm. The tip of the wall will penetrate either the organic silt or natural silty sand which underlies the man-made fill or the earth cofferdam fill. Cutoff wall locations and profiles are shown on Plates 8-4, 8-5, 8-7 and 8-8.

On the Boston side of Stage 2 Cofferdam, seepage cutoff walls have been provided extending from the ends of sheet pile cells to shore, but full closure was considered not practical because of drilling experience and historical data indicates that the man-made fill in the abandoned ramp area may contain large granite blocks and boulders which may obstruct the driving of the piles. Therefore, because of the discontinuity of the cutoff wall (and for slope stability purpose), the inboard dike slopes will be covered with crushed stone fill to control seepage below El. 110.0 along the westerly arm and below El. 95.0 on the remaining slopes. Cutoff wall locations and profiles are shown on Plate 8-9. The contractor will be required to control interior seepage by any means necessary to maintain all areas dry and stable.

b. Cell Cofferdams. In general, the sheets of the cells will be driven from 3 to 5 feet (and possibly less) into the till. Since the penetration will be small, a gravel berm will be placed along the entire inboard perimeter of cells (prior to unwatering) for the purpose of controlling exit seepage at toe of cell and for protecting the cell toe area against seepage erosion. The berm will be machine shaped as shown on Plate 8-4 after the area is unwatered.

In two limited reaches, all or a portion of the gravel berm must be removed for the construction of portions of the large lock. In these reaches, interior drains utilizing 3/4 inch stone will be constructed within the cells and arcs adjacent to the inward face. These interior drains will be drained by means of 1-inch diameter holes. The holes will be spaced on 4-inch centers for a 5-foot total height on two sheet piles per circular cell and one sheet pile per interconnecting cell. The holes will be cut in each sheet pile before driving. During the removal of the gravel berm, the effectiveness of the interior drain will be examined.

31. PRESSURE RELIEF. The boring data indicates that there are fractured zones in the argillite bedrock beneath the impervious till. The fractured zones can very well provide direct seepage path across the rock on both sides of the cofferdam and reflect full river head inside the cofferdam. The bedrock is covered by the relatively very impervious till which will prevent release of excess hydrostatic pressure in the rock and possibly create an unstable foundation condition in areas where the total overburden weight is not large enough to counteract the uplift pressure.

Hydrostatic pressure relief in the bedrock along the entire inboard cofferdam perimeters is considered necessary and a bedrock water pressure relief system will be constructed as part of the required work.

The system will consist of relief wells spaced 20 feet apart, 4-inch minimum inside diameter extending 25 feet below the rock surface.

Air activated diaphragm type piezometers will be provided to monitor relief well operation and to determine if additional pressure relief measures are necessary during cofferdam unwatering and prior to excavation below the organic silt for foundation of permanent structures (which will not be done until it is determined that the pressure relief system is adequate).

Some of the relief wells in Stage 2 Cofferdam along the westerly arm of the cofferdam will require pumping from within because their discharge points will be too far above the adjacent required foundation excavation area. (See Plate 8-5).

Relief wells will be kept operational until the work is complete and the cofferdam area is flooded.

After flooding of the cofferdam area, all but thirteen of the relief wells will be plugged with cement grout so as to prevent piping type of erosion in the foundation. Relief wells not to be plugged are the ones too far from permanent structures to cause damage. (See Plate 8-4). Locations and details of relief wells and piezometers are shown on Plates 8-4, 8-5 and 8-10.

M. AVAILABILITY AND CHARACTERISTICS OF FILL MATERIALS

32. <u>CELL FILL MATERIALS</u>. Cell fill material is commercially available from natural deposits located within a haul distance of 20 miles by truck and 70 miles by rail from the project site; however, local experience to date indicates that rail hauling is not competitive for quantities smaller than one-half million yards.

Cell fill materials will consist of natural gravelly sand, sandy gravel or sand. The specifications will permit the use of gravel fill and gravel berm materials. (See para. 33 below). In addition, it will permit the use of well graded sand containing at least 10 percent by weight of particles retained on the No. 16 sieve and not more than 10 percent of particles passing the No. 200 sieve.

33. <u>GRAVEL MATERIALS</u>. Availability and characteristics are as described for gravel materials in DM No. 4, EMBANKMENTS AND FOUNDATIONS.

a. <u>Gravel Fill</u>. The gradation is identical to that of the gravel fill material for the permanent work.

U.S. Sieve Designation	Per Cent Passing by Weight
6 inch	100
2 inch	75-100
1 inch	50-85
No. 4	40-70
No. 40	20-50
No. 200	0-8

b. Gravel Berm. Gravel berm material will be graded as above for gravel fill except for the following deviation:

No. 4	30-50
No. 40	10-35

34. ROCK MATERIALS. Availability and characteristics of protection stone and crushed stone are as described for Protection Stone in DM No. 4, EMBANKMENTS AND MATERIALS and as for coarse concrete aggregate in DM No. 3, CONCRETE MATERIALS.

a. Type I, Protection Stone. Well graded quarried rock graded from 5 to 300 pound sizes.

b. Crushed Stone Fill. Gradation and quality will equal to that required for coarse aggregate for portland cement concrete. The crushed stone fill and interior drain materials will have a maximum size of 1-1/2 and 3/4 inches, respectively.

N. CONSTRUCTION CONSIDERATIONS

35. EXCAVATIONS.

a. River Banks. To insure stability during construction the specifications will require that the excavations for the bypass channel on the Boston side and for the removal of the organic silt on the Charlestown side will be done in such a manner that at no time will the slopes be steeper than final slopes.

b. Cofferdam Foundation Areas. Organic silts, very loose silty sand (in areas where boring data show "N" values less than 4) and sandy silt will be removed prior to construction of the cofferdams.

c. Foundations of Permanent Structure. The excavation for the foundation of the permanent structures (except for the removal of organic silt) will not be done until the areas are unwatered and the piezometer readings show that there is no excess water pressure in in the rock. In the inboard area of Stage 2 Cofferdam, the gravel fill in the area east of the cofferdam interior wall will not be excavated until said wall is installed.

d. Bypass Channel. Bypass channel excavation and placement of protection stone will be completed prior to construction Stage 1 Cells. The excavation below El. 106 in the Bypass channel area adjacent to the twin piers of the J. F. Fitzgerald Expressway Bridge will not be done until the protective steel sheeting around the piers is installed.

36. CELL FILLING. Interconnecting arc cells will not be filled prior to filling of adjacent circular cells. The contractor will not be restricted to any specific method for placement of cell fill material. Dike earth fill material will not be placed against empty cells.

37. EARTH COFFERDAM. The dumped and compacted gravel fills for earth cofferdam embankments will be placed as required for permanent gravel fill embankments. The dumped gravel fill will be placed by methods which will produce the most dense and nonsegregated fill that can be expected by methods when placing in water. The specification will require a sequence of construction that will insure no failure of the abutments (excavation and/or existing fill slopes against which fill is placed) due to fill placement. The following procedure for placing dumped gravel fill will be required. The dumped gravel fill below elevation 90 will be placed either by discharging from a bottom dump barge or by lowering a skip or bucket to the earth or fill surface and discharging at that elevation. It is expected that both methods will be used. The material will be placed uniformly over the entire fill area and the elevations of the top of the uncompleted fill (exclusive of exterior slope) will not vary by more than 10 feet. The above placement procedure may be used for dumped gravel fill between elevations 90 and 105. The contractor may place dump gravel fill material between elevations 90 and 105, where possible, by extending the fill from the abutment with the top of the fill at elevation 105. The material shall be dumped on the surface at elevation 105 near the edge of the horizontal surface and pushed over the edge with a bulldozer or similar equipment. The contractor will be required to excavate fill, place fill, and trim, as necessary to shape the exterior slopes and surfaces to the lines and grades shown on the drawings.

38. STEEL SHEET PILING.

a. Cofferdam Cells. Pile length estimate is based on the assumption that steel sheeting will penetrate 3 feet below the surface of the till on all areas except in cell areas across the easterly arms of both cofferdams where the penetration is assumed to be 5 feet below the till surface. Penetration depths were selected on the basis of local experience. The contractor will be given the ordering pile lengths and as a result of large variation in the till surface beneath many cells, the contractor will be required to drive all piles until the butt elevation is at El 118, unless modified by the Contracting Officer.

The steel sheeting will be installed with the aid of a double deck template. To avoid "toe-in" or "toe-out" and permit easier driving, all sheets will be laced and set prior to start of pile driving and the sheets will be driven progressively deeper (at increments) along the full circle or arc.

Prior to filling of the cells with cell fill material, the interlocks will be inspected by diver and sheeting with open or torn interlocks will be removed and replaced.

b. Cutoff Wall. The steel sheet pile cutoff wall within any embankment will be installed after construction of the embankment.

c. New Protective Steel Sheeting. The new protective steel sheeting will be installed prior to excavation below El 106 in the Bypass channel excavation area adjacent to the twin highway piers they are to protect. For ease of installation, the contractor will be allowed to excavate to the El 106 adjacent to the piers immediately before installation of sheeting.

The purpose of the sheeting is to protect the foundati on of the piers against erosion.

39. STAGE 2 COFFERDAM INTERIOR WALL. The Stage 2 cofferdam interior wall will be installed after unwatering of the cofferdam but prior to excavation in the lock foundation area adjacent to the wall.

40. COFFERDAM SURVEILLANCE AND SAFETY FEATURES. Requirements for contractor surveillance and operation of the cofferdam will be stated in the contract documents. Movement monitoring procedures, alarm systems, personnel escape facilities and flooding criteria will be stipulated and enforced.

a. Movement Monitoring Procedure. Movement monitoring procedure will consist of requirement for reading horizontal and vertical movements at observation points set up on top of the cells. Readings will be taken prior to unwatering, during unwatering and at set intervals after unwatering. The diameter of the cells will also be measured as part of the movement monitoring procedure.

b. Alarm System. An alarm system will be provided and procedures for rapid personnel evacuation will be set up as a contract requirement.

c. Escape Facilities. Escape ladders will be provided at eight cells in Stage 1 Cofferdam and two cells at Stage 2 Cofferdam. In addition, two escape ladders will be provided at the inboard face of the large lock in Stage 2.

O. INSTRUMENTATION

41. GENERAL. Instrumentation will include the following:

a. Piezometers. Air activated piezometers will be used to measure water pressure in the top few feet of bedrock.

b. Observation Wells. Observation wells will be of the open-type vertical standpipe with screened tips. Observation wells will be used to measure the saturation line inside selected cells.

c. Movement Monitors. Cell movement observation points will be set up on top of each circular cell to measure horizontal and vertical movements, and to measure any change in the cell diameter.

P. COST ESTIMATE

42. GENERAL. The total costs for the cofferdams including the excavation for the bypass channel and 11% for contingencies is $4,845,000. A detailed cost estimate is shown in Table 1.

TABLE 1

Description	Quantity	Unit	Unit Price	Estimated Amount
A. Stage I Cofferdam				
Cofferdam Excavation	66,000	c.y.	$ 3.50	$ 231,000
Sheet Piling	4,450	Ton	450.00	2,002,500
Cell and Gravel Fill	107,000	c.y.	4.55	486,800
Dewatering	1	Job	L.S.	420,000
Relief Wells	79	ea.	1800.00	142,200
Piezometers	6	ea.	4200.00	25,200
Observation Wells	12	ea.	700.00	8,400
Removal of Cell and Gravel Fill	80,000	c.y.	2.10	168,000
Sheet Pile Cutoff Wall	6,300	s.f.	4.10	25,800
Sheet Pile Protection Bent 1.	3,000	s.f.	4.50	13,500
Fendering and Dolphins	1	Job	L.S.	18,000
Obstruction Lights	1	Job	L.S.	6,000
Subtotal				$3,547,400
B. Stage II Cofferdam				
Cofferdam Excavation	12,300	c.y.	$ 3.50	$ 43,050
Sheet Piling	1,120	Ton	220.00	224,600
Cell Fill	26,000	c.y.	2.25	58,500
Dewatering	1	Job	L.S.	110,000
Relief Wells	24	ea.	1700.00	40,800
Observation Wells	3	ea.	700.00	2,100
Piezometers	3	ea.	2500.00	7,500
Removal of Cell Fill	20,000	c.y.	2.10	42,000
Sheet Pile Cutoff Wall	16,100	s.f.	3.90	62,790
Cofferdam Interior Wall	1	Job	L.S.	36,400
Subtotal				$ 627,740
C. Bypass Channel				
Excavation	30,000	c.y.	$ 3.50	$ 105,000
Class I Protection Stone	7,000	Ton	8.00	56,000
Removal of Protection Stone	7,000	Ton	4.00	28,000
Subtotal				$ 189,000
TOTAL COFFERDAMS				$4,364,140
Contingencies				480,860
		TOTAL		$4,845,000

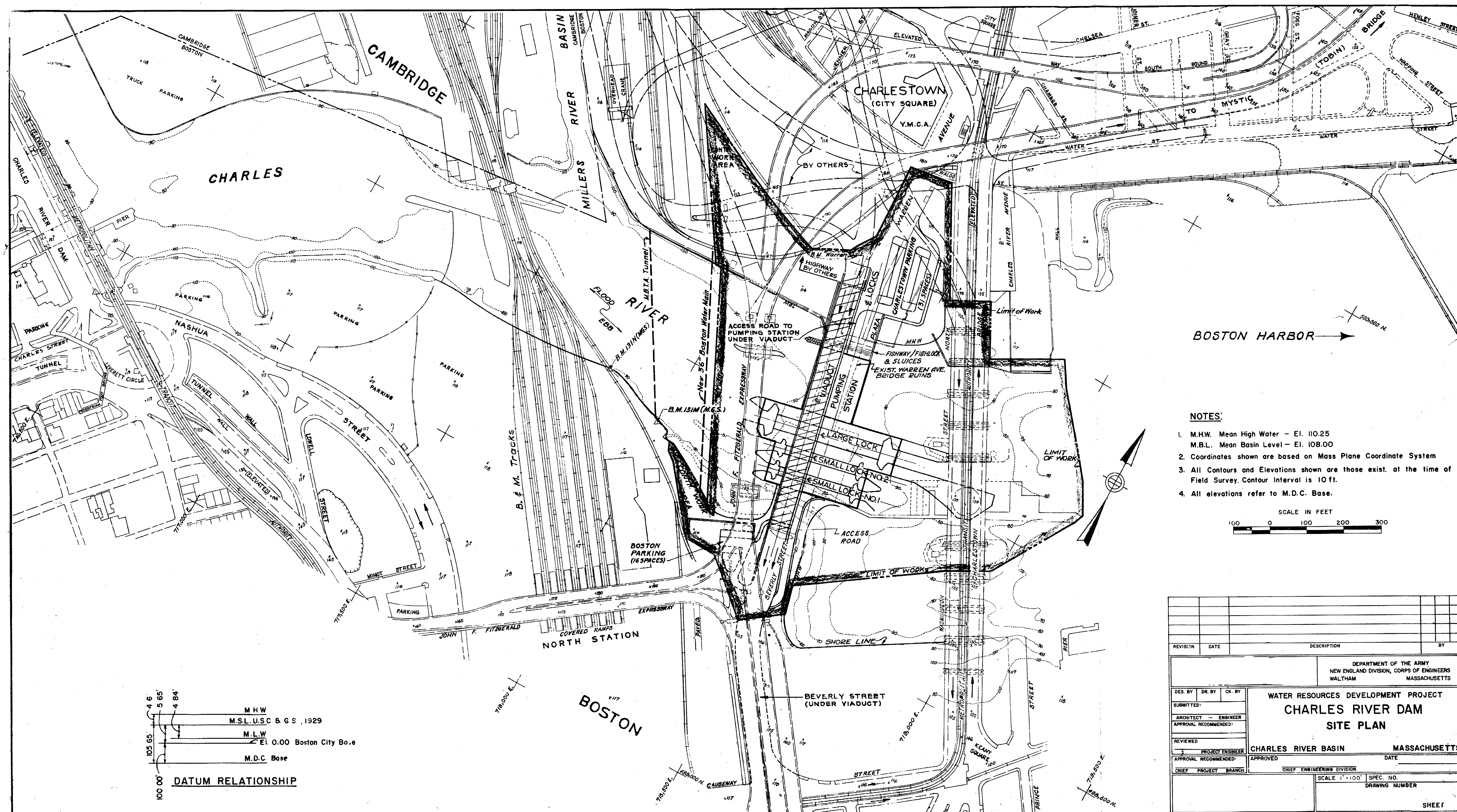
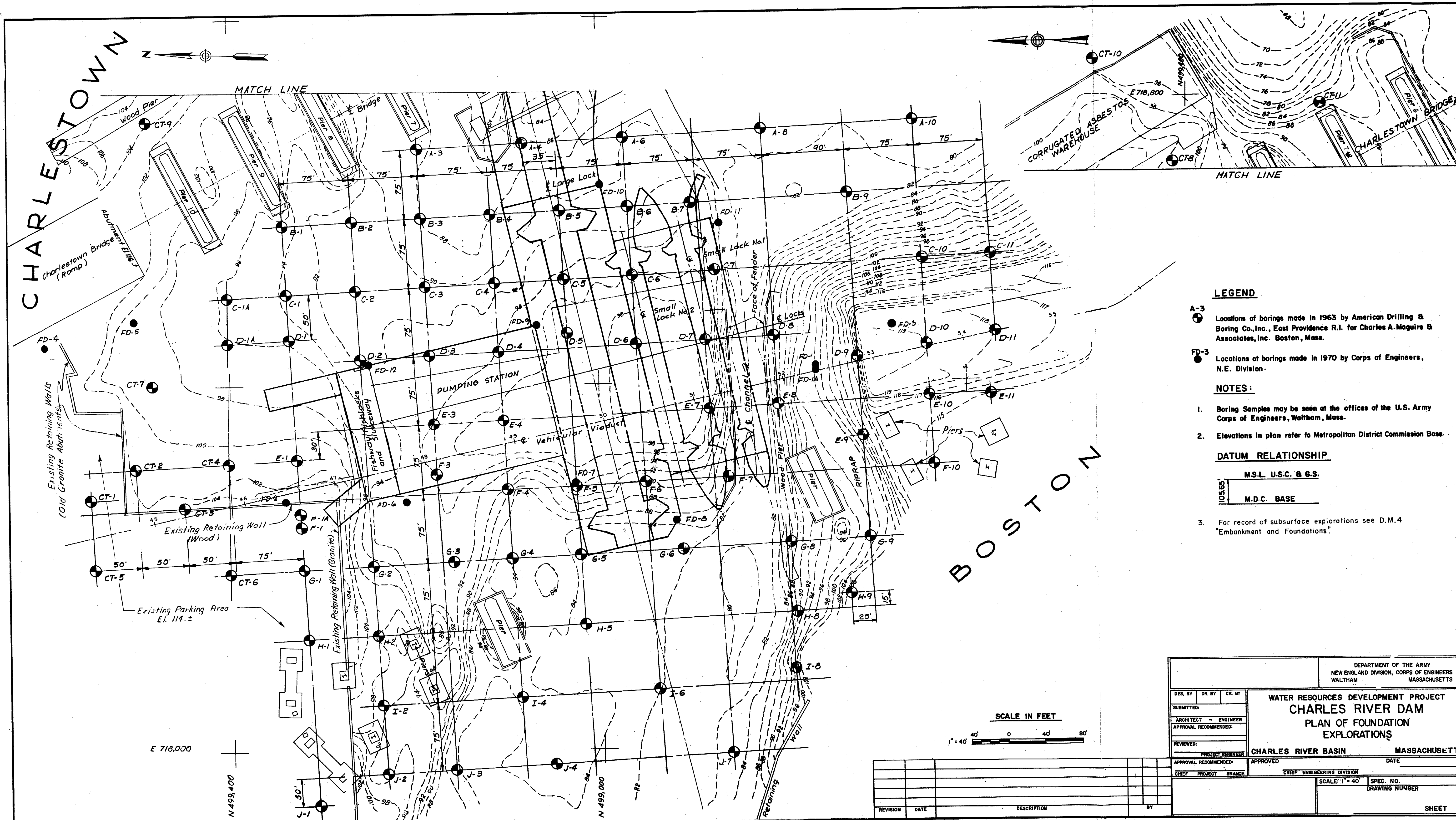

CAMBRIDGE
CHARLESTOWN (CITY SQUARE)
Y.M.C.A.
CHARLES
RIVER
BASIN
MILLERS RIVER
BOSTON HARBOR
BOSTON
NORTH STATION
B. & M. Tracks
CHARLES RIVER DAM
NASHUA STREET
LOWELL STREET
MINOT STREET
JOHN F. FITZGERALD EXPRESSWAY
COVERED RAMPS
BOSTON PARKING (16 SPACES)
CHARLESTOWN PARKING (31 SPACES)
ACCESS ROAD TO PUMPING STATION UNDER VIADUCT
HIGHWAY BY OTHERS
BY OTHERS
CONTR. WORK AREA
LOCKS
PLAZA
VIADUCT
PUMPING STATION
LARGE LOCK
SMALL LOCK NO. 2
SMALL LOCK NO. 1
FISHWAY/FISHLOCK & SLUICES
EXIST. WARREN AVE. BRIDGE RUINS
MHW
ACCESS ROAD
LIMIT OF WORK
Limit of Work
SHORE LINE
New 36" Boston Water Main
M.B.T.A. Tunnel
B.M. 131N (M.G.S.)
B.M. 131M (M.G.S.)
B.M. Warren
FLOOD
EBB
BEVERLY STREET (UNDER VIADUCT)
CHARLESTOWN BRIDGE
NORTH WASHINGTON STREET
KEANY SQUARE
CAUSEWAY
PRINCE STREET
WATER ST.
CHELSEA ST.
TO MYSTIC
(TOBIN) BRIDGE
HENLEY STREET
ELEVATED
CITY SQUARE
WARREN AVENUE
WALDO
PIER
CHARLES RIVER DAM
CHARLES STREET
TUNNEL
LEVERETT CIRCLE
CAMBRIDGE BOSTON
TRUCK PARKING
PARKING
M H W
M.S.L. U.S.C & G.S., 1929
M.L.W.
El. 0.00 Boston City Base
M.D.C Base
4.6'
5.65'
4.84'
105.65'
100.00'
DATUM RELATIONSHIP
NOTES:
1. M.H.W. Mean High Water – El. 110.25
M.B.L. Mean Basin Level – El. 108.00
2. Coordinates shown are based on Mass Plane Coordinate System
3. All Contours and Elevations shown are those exist. at the time of Field Survey. Contour Interval is 10 ft.
4. All elevations refer to M.D.C. Base.
SCALE IN FEET
100 0 100 200 300
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS
DES. BY
DR. BY
CK. BY
SUBMITTED:
ARCHITECT – ENGINEER
APPROVAL RECOMMENDED:
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
SITE PLAN
CHARLES RIVER BASIN MASSACHUSETTS
APPROVED
DATE
CHIEF ENGINEERING DIVISION
SCALE 1" = 100'
SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-1



LEGEND

A-3 Locations of borings made in 1963 by American Drilling & Boring Co., Inc., East Providence R.I. for Charles A. Maguire & Associates, Inc. Boston, Mass.

FD-3 Locations of borings made in 1970 by Corps of Engineers, N.E. Division.

NOTES:

1. Boring Samples may be seen at the offices of the U.S. Army Corps of Engineers, Waltham, Mass.
2. Elevations in plan refer to Metropolitan District Commission Base.

DATUM RELATIONSHIP

M.S.L. U.S.C. & G.S.

105.65'

M.D.C. BASE

3. For record of subsurface explorations see D.M.4 "Embankment and Foundations".

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY	DR. BY	CK. BY

SUBMITTED:

ARCHITECT - ENGINEER

APPROVAL RECOMMENDED:

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

PLAN OF FOUNDATION EXPLORATIONS

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

CHIEF ENGINEERING DIVISION

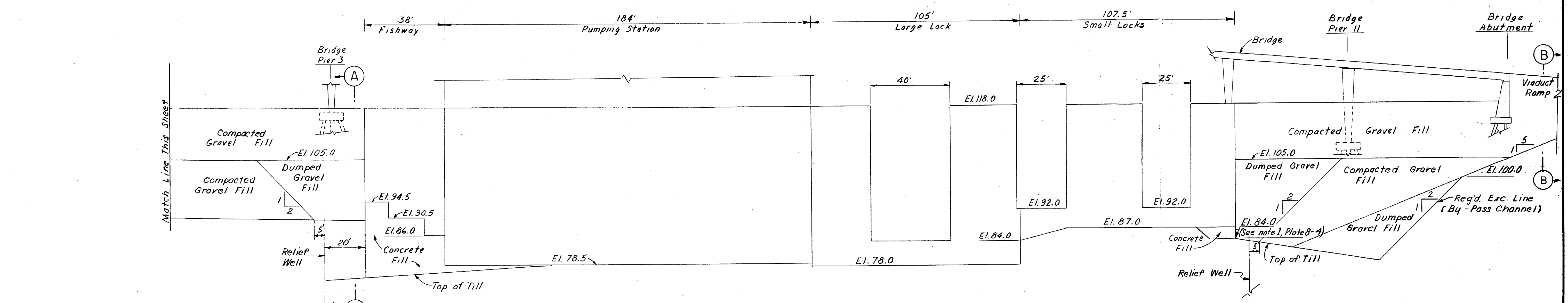
SCALE: 1" = 40' SPEC. NO.

DRAWING NUMBER

SHEET

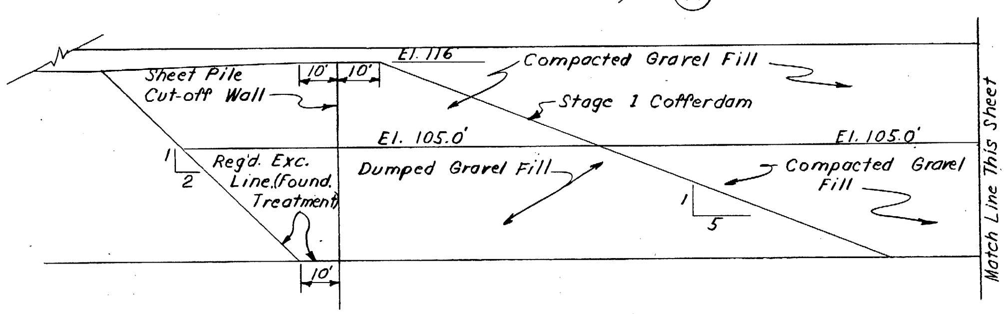
REVISION	DATE	DESCRIPTION	BY

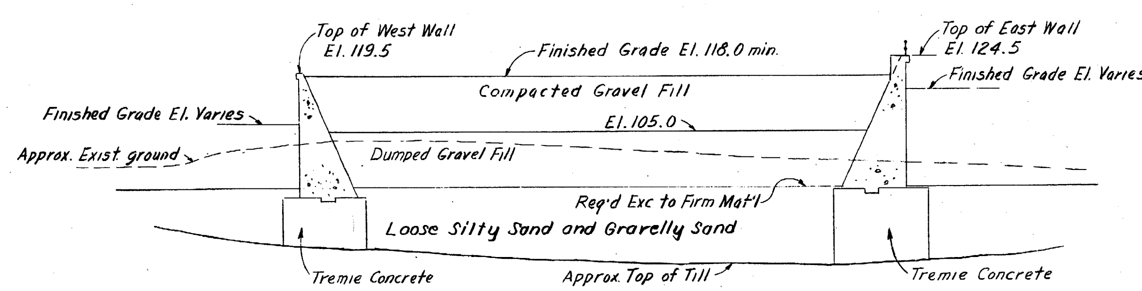
PLATE 8-2



PROFILE ALONG VIADUCT BASELINE

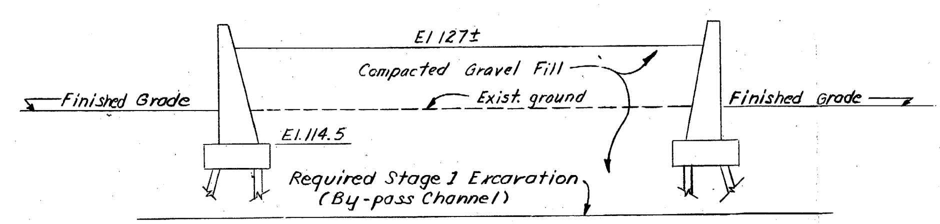
SCALE: HOR 1"=20 VER 1"=10'





SECTION A-A

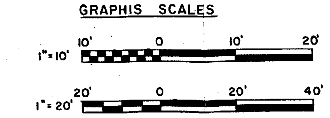
SCALE 1"=20'



SECTION B-B

SCALE 1"=10'

GRAPHIS SCALES



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY

SUBMITTED:

ARCHITECT - ENGINEER

APPROVAL RECOMMENDED:

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

PROFILE AND SECTIONS

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

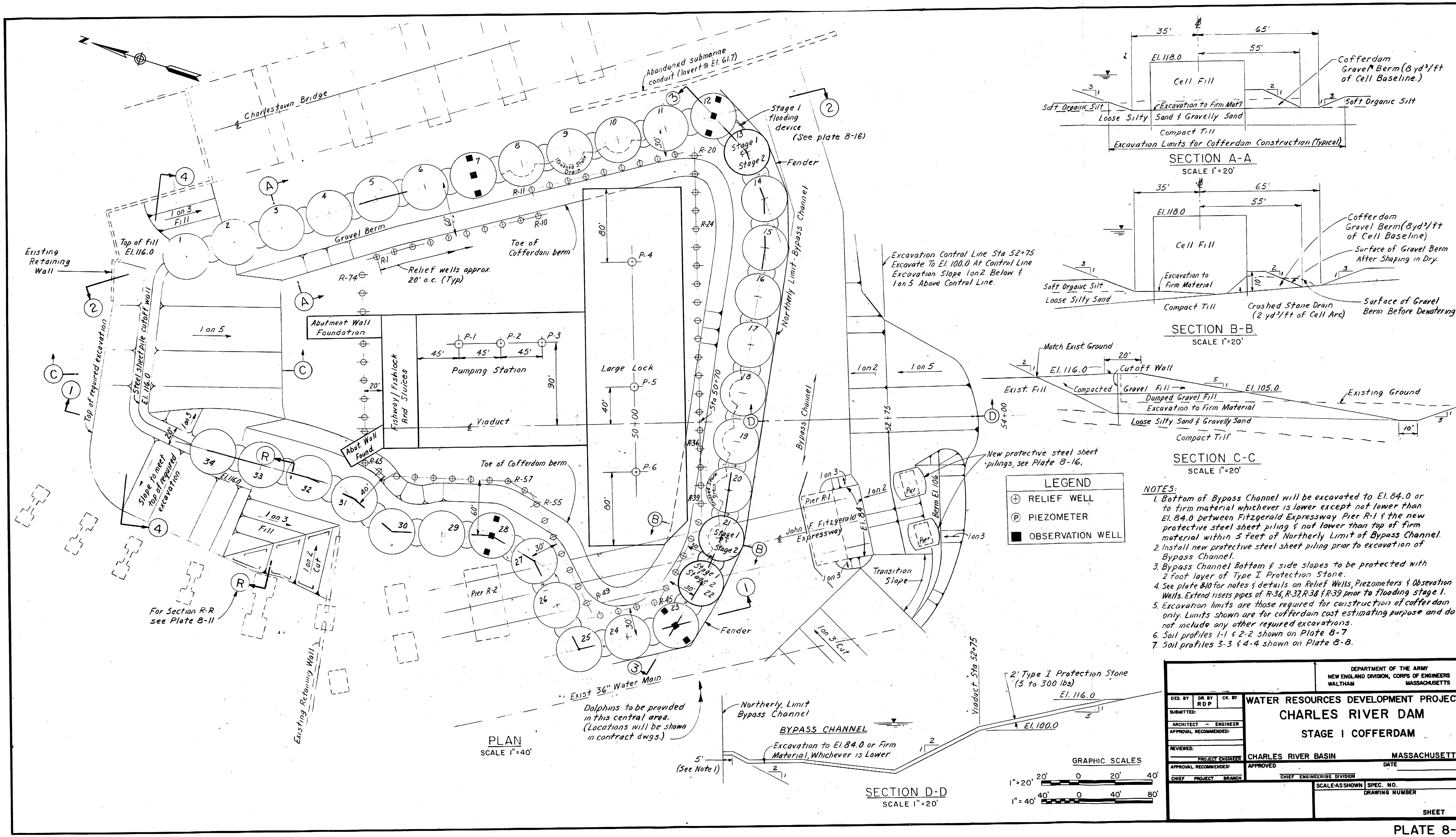
CHIEF ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO.

DRAWING NUMBER

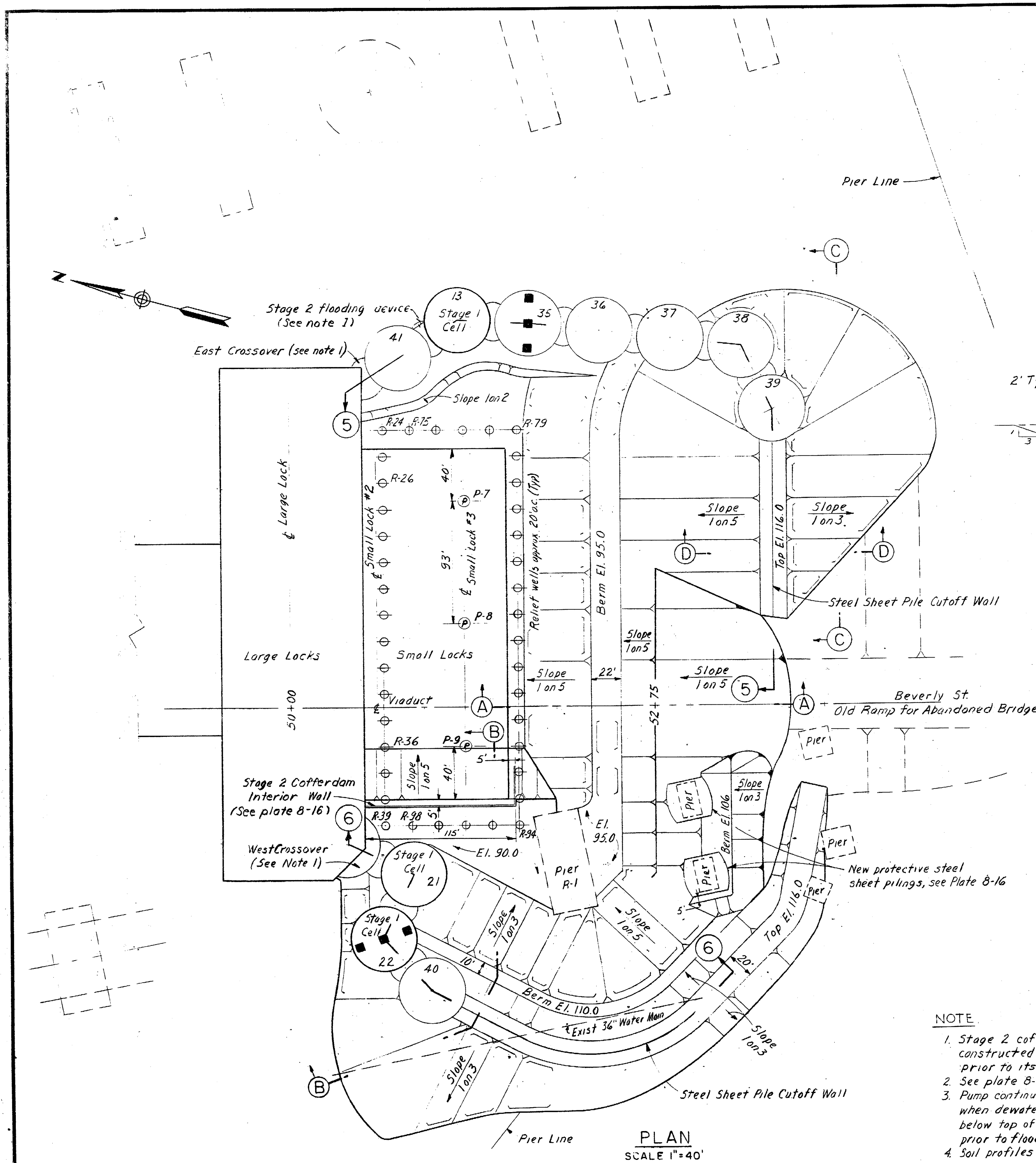
SHEET

PLATE 8-3

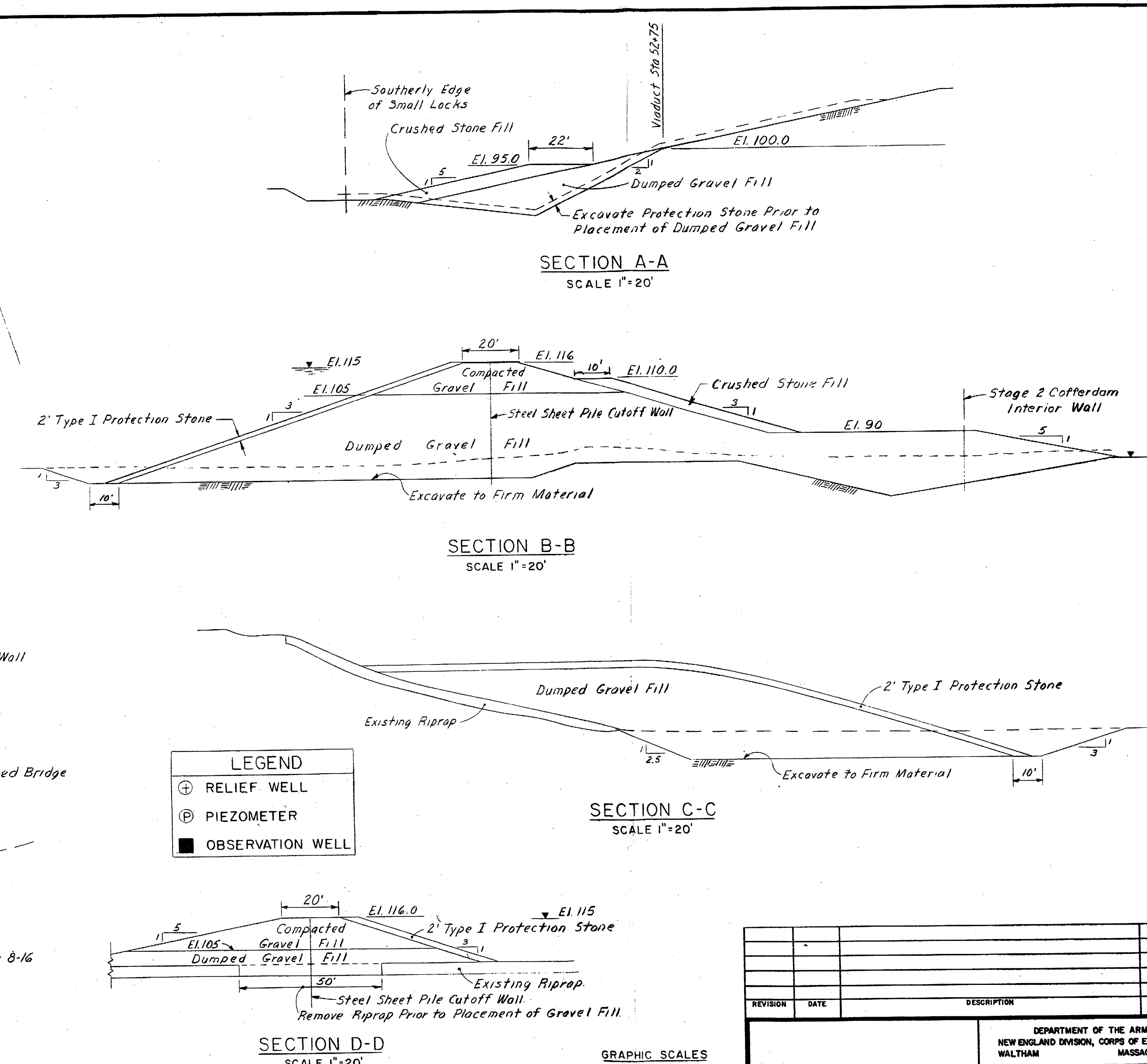


Charlestown Bridge
Abandoned submarine conduit (Invert @ El. 61.7)
Stage I flooding device (See plate 8-16)
Fender
Existing Retaining Wall
Top of Fill El. 116.0
1 on 3 Fill
Gravel Berm
Toe of Cofferdam berm
Relief wells approx. 20' o.c. (Typ)
Steel sheet pile cutoff wall
Top of required excavation
1 on 5
Abutment Wall Foundation
Fishway / Fishlock And Sluices
Pumping Station
Large Lock
Viaduct
Abut. Wall Found.
Northerly Limit - Bypass Channel
Bypass Channel
Excavation Control Line Sta 52+75 Excavate To El. 100.0 At Control Line Excavation Slope 1on2 Below & 1 on 5 Above Control Line.
Slope to meet top of required excavation
1 on 2 Cut
For Section R-R see Plate 8-11
Pier R-2
Pier R-1
John F. Fitzgerald Expressway
Berm El. 106
Transition Slope
1 on 3 Cut
New protective steel sheet pilings, see Plate 8-16.
Exist 36" Water Main
Dolphins to be provided in this central area. (Locations will be shown in contract dwgs.)
Existing Retaining Wall
PLAN
SCALE 1"=40'
LEGEND
RELIEF WELL
PIEZOMETER
OBSERVATION WELL
Cofferdam Gravel Berm (8 yd³/ft of Cell Baseline.)
Cell Fill
El. 118.0
Soft Organic Silt
Loose Silty Sand & Gravelly Sand
Excavation to Firm Mat'l
Compact Till
Excavation Limits for Cofferdam Construction (Typical)
SECTION A-A
SCALE 1"=20'
Cofferdam Gravel Berm (8 yd³/ft of Cell Baseline)
Surface of Gravel Berm After Shaping in Dry.
Excavation to Firm Material
Loose Silty Sand
Crushed Stone Drain (2 yd³/ft of Cell Arc)
Surface of Gravel Berm Before Dewatering
SECTION B-B
SCALE 1"=20'
Match Exist. Ground
El. 116.0
Cutoff Wall
El. 105.0
Exist. Fill
Compacted Gravel Fill
Dumped Gravel Fill
Excavation to Firm Material
Loose Silty Sand & Gravelly Sand
Existing Ground
Compact Till
SECTION C-C
SCALE 1"=20'
NOTES:
1. Bottom of Bypass Channel will be excavated to El. 84.0 or to firm material whichever is lower except not lower than El. 84.0 between Fitzgerald Expressway Pier R-1 & the new protective steel sheet piling & not lower than top of firm material within 5 feet of Northerly Limit of Bypass Channel.
2. Install new protective steel sheet piling prior to excavation of Bypass Channel.
3. Bypass Channel Bottom & side slopes to be protected with 2 foot layer of Type I Protection Stone.
4. See plate 8-10 for notes & details on Relief Wells, Piezometers & Observation Wells. Extend risers pipes of R-36, R-37, R-38 & R-39 prior to flooding stage 1.
5. Excavation limits are those required for construction of cofferdam only. Limits shown are for cofferdam cost estimating purpose and do not include any other required excavations.
6. Soil profiles 1-1 & 2-2 shown on Plate 8-7
7. Soil profiles 3-3 & 4-4 shown on Plate 8-8.
Northerly Limit Bypass Channel
BYPASS CHANNEL
Excavation to El. 84.0 or Firm Material, Whichever is Lower
5' (See Note 1)
2' Type I Protection Stone (5 to 300 lbs)
El. 116.0
El. 100.0
Viaduct Sta 52+75
SECTION D-D
SCALE 1"=20'
GRAPHIC SCALES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STAGE I COFFERDAM
CHARLES RIVER BASIN MASSACHUSETTS
DR. BY RDP
SCALE: AS SHOWN

PLATE 8-4



PLAN
SCALE 1"=40'



LEGEND
- ⊕ RELIEF WELL
- Ⓟ PIEZOMETER
- ■ OBSERVATION WELL

NOTE
1. Stage 2 cofferdam connections, crossovers & interior fills shall be constructed to the extent possible inside stage I cofferdam prior to its flooding. See Plates 8-15 and 8-16.
2. See plate 8-10 for notes and details on relief wells, piezometers and observation wells.
3. Pump continuously from wells R39, R92, R93, R94, R95, R96, R97 and R98 when dewatering is below elev. of fill at well. Maintain water level in well 12' below top of fill at well. Have 2 stand-by pumps. Extend riser pipe of R36, R37, R38 & R-39 prior to flooding stage I, cofferdam
4. Soil profiles 5-5 and 6-6 are shown on Plate 8-9.

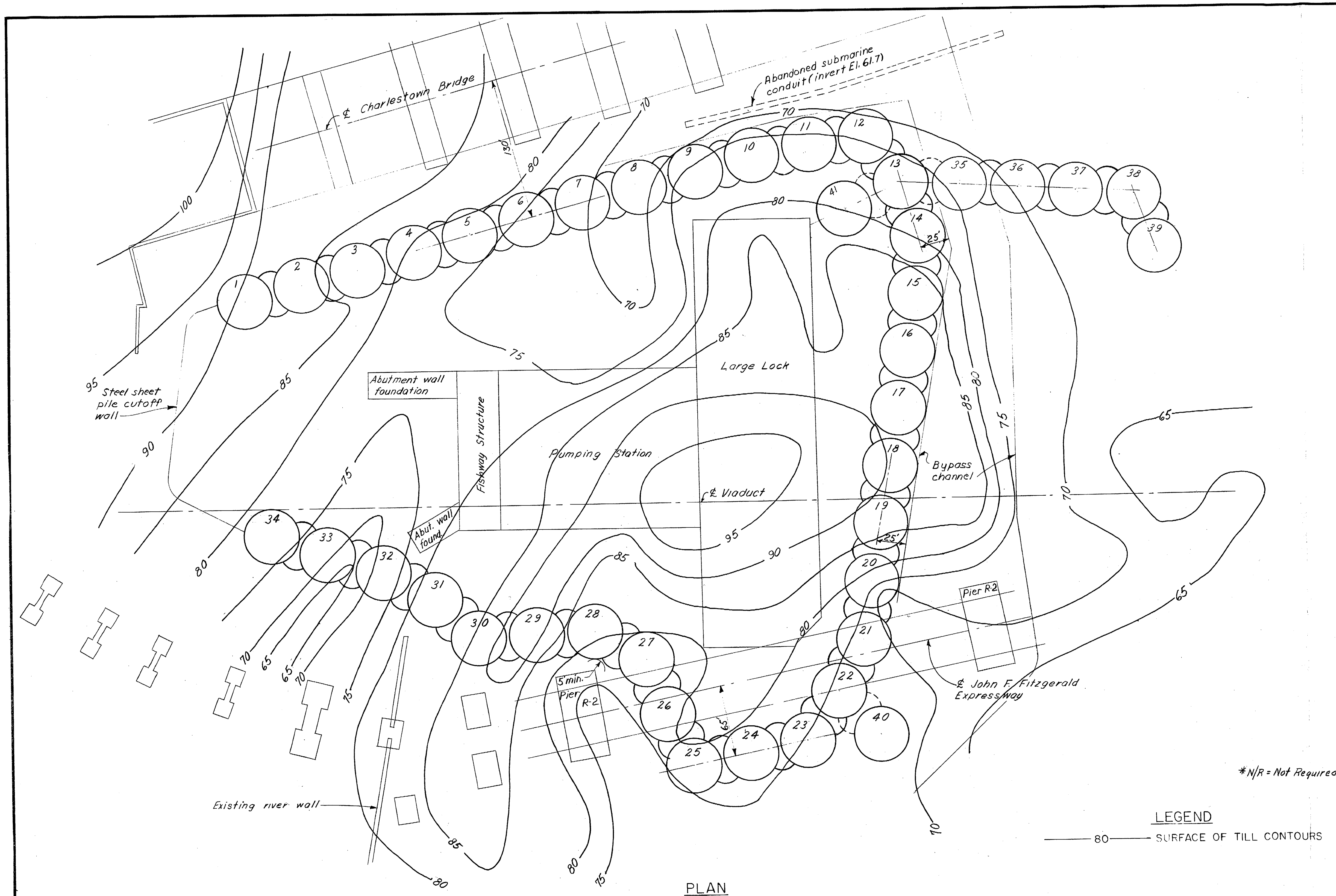
GRAPHIC SCALES
1"=20' 20' 0 20' 40'
1"=40' 40' 0 40' 80'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STAGE 2 COFFERDAM
CHARLES RIVER BASIN MASSACHUSETTS
APPROVED DATE
CHIEF ENGINEERING DIVISION
SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

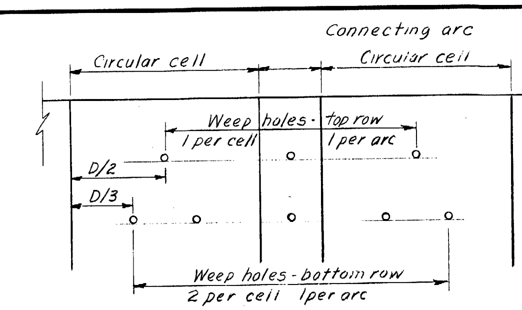


PLAN
SCALE 1" = 40'

LEGEND
—— 80 —— SURFACE OF TILL CONTOURS

GRAPHIC SCALES
1" = 40' 40' 0 40' 80'

*N/R = Not Required



TYPICAL WEEP HOLE LAYOUT
NOT TO SCALE

	CELL NO	WEEP HOLE ELEVATION TOP 1 PER CELL	WEEP HOLE ELEVATION BOTTOM 2 PER CELL	CONNECTING ARC NO	WEEP HOLE ELEV TOP 1 PER CELL	WEEP HOLE ELEV BOTTOM 2 PER CELL
Stage 1 Cofferdam	1	N/R*	N/R	1-2	N/R	N/R
	2	"	"	2-3	"	"
	3	"	"	3-4	"	"
	4	"	"	4-5	"	"
	5	100	"	5-6	100	"
	6	"	93	6-7	"	90
	7	"	90	7-8	"	"
	8	"	"	8-9	"	"
	9	"	"	9-10	"	"
	10	"	"	10-11	"	"
	11	"	95	11-12	"	95
	12	"	"	12-13	"	"
	13	"	"	13-14	"	"
	14	"	"	14-15	"	N/R
	15	"	N/R	15-16	"	"
	16	"	"	16-17	"	"
	17	"	"	17-18	102	"
	18	102	"	18-19	"	"
	19	"	"	19-20	100	"
	20	100	95	20-21	"	90
	21	"	90	21-22	"	"
	22	"	"	22-23	"	"
	23	"	"	23-24	"	"
	24	"	93	24-25	"	93
	25	"	"	25-26	"	"
	26	"	"	26-27	"	90
	27	"	90	27-28	"	93
	28	"	95	28-29	"	N/R
	29	"	N/R	29-30	"	"
	30	"	"	30-31	"	"
	31	"	"	31-32	"	"
	32	"	"	32-33	"	"
	33	"	"	33-34	N/R	"
	34	N/R	N/R			
Stage 2 Cofferdam	41	100	95	LL-41	100	95
	13	"	"	41-13	"	"
	35	"	90	13-35	"	90
	36	"	95	35-36	"	92
	37	"	N/R	36-37	"	N/R
	38	N/R	"	37-38	N/R	"
	39	"	"	38-39	"	"
	21	100	92	LL-21	100	92
	22	N/R	N/R	21-22	N/R	N/R
	40	"	"	22-40	"	"

Table 1 Cofferdam weep hole location

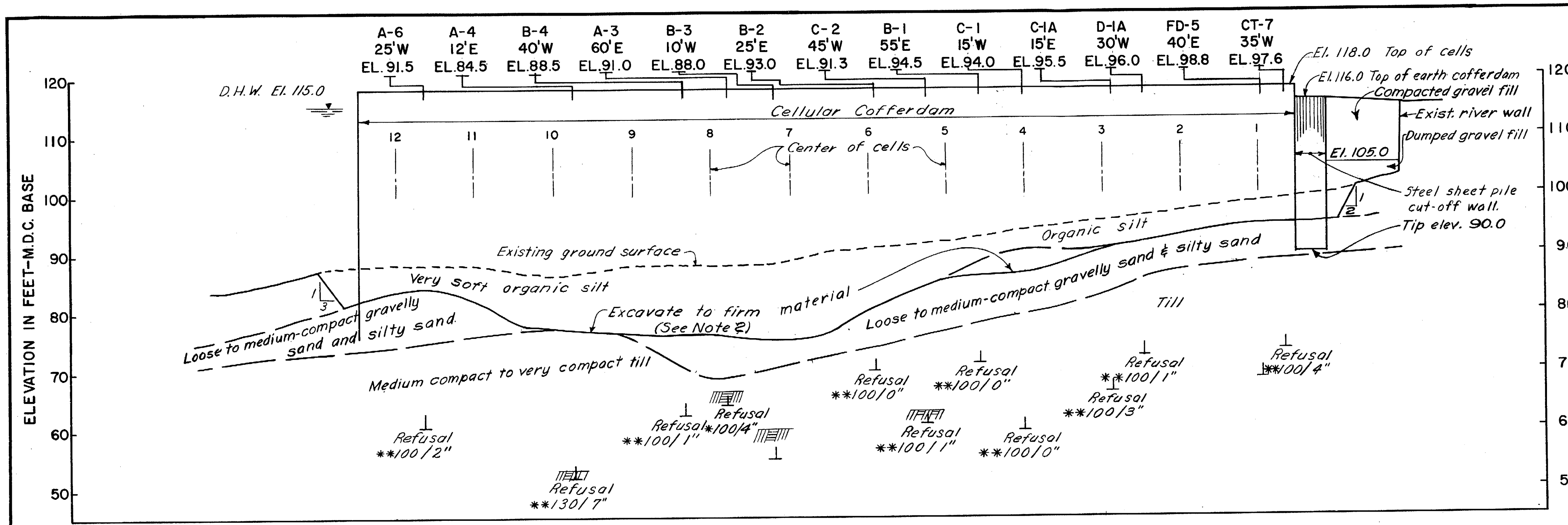
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY | CK. BY

SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

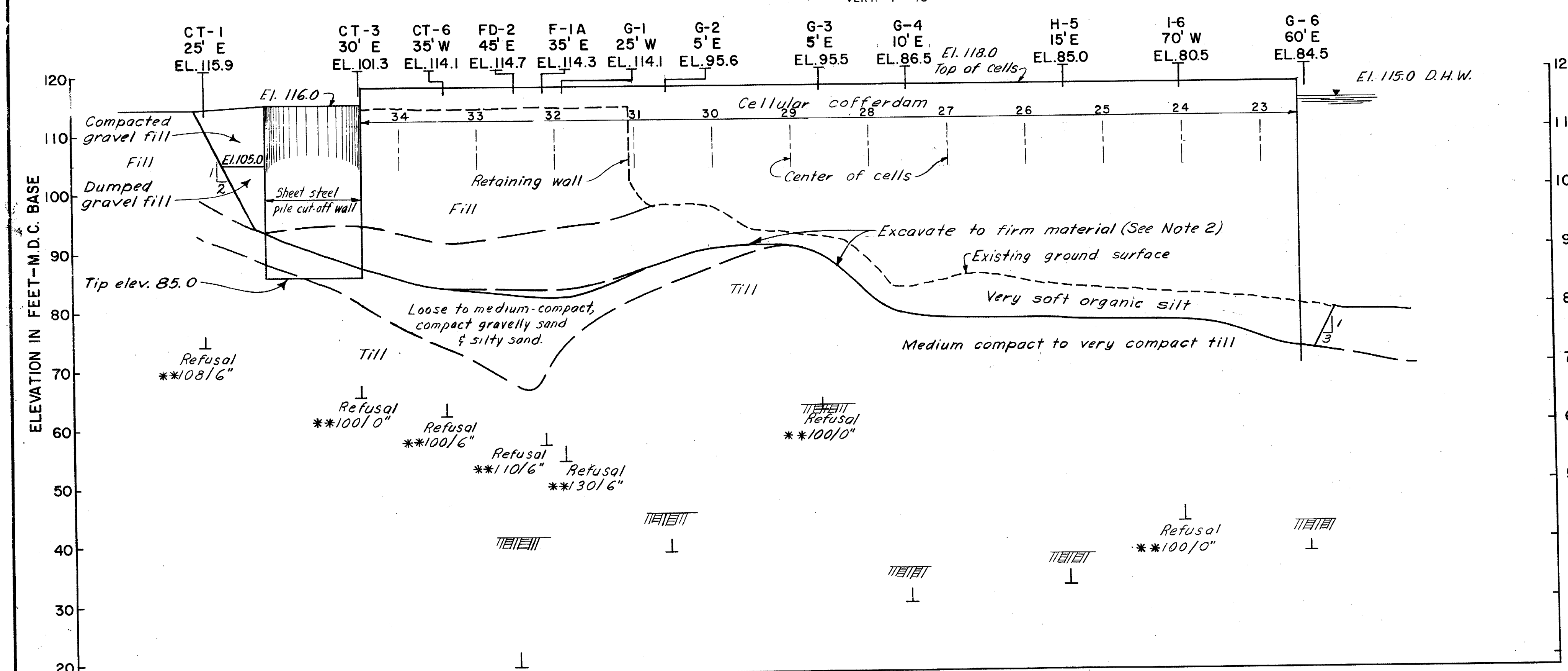
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
CELLULAR COFFERDAM LAYOUT AND TILL CONTOURS
CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE
CHIEF ENGINEERING DIVISION
SCALE: AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET



PROFILE 2-2

SCALES HORIZ. = 1" - 40' VERT. = 1" - 10'



PROFILE 1-1

SCALES HORIZ. = 1" - 40' VERT. = 1" - 10'

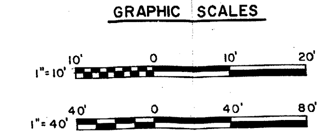
LEGEND

G-2	Boring Designation
25'W	Distance from Profile Baseline Westerly Direction.
El. 91.5	Elevation of Ground Surface at Boring Location.
⊥	Bottom of Boring
	Top of Rock
Refusal 110/6"	Refusal Indicated by 110 Blows on Total Penetration of 6 Inches of Open End "AW" Rod (1¾" O.D.)
*	140 Pound Hammer with 30" Fall
* *	300 Pound Hammer with 24" Fall

NOTES:

1. Boring locations shown on Plate 8-2
2. Excavation to firm material will include removal of organic silt and of soil with "N" value of less than 4, where "N" equals Standard Penetration Test Value.
3. Profile locations shown on Plate 8-4

GRAPHIC SCALES



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY

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APPROVAL RECOMMENDED:

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WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

STAGE I COFFERDAM

SOIL PROFILES NO. I

CHARLES RIVER BASIN MASSACHUSETTS

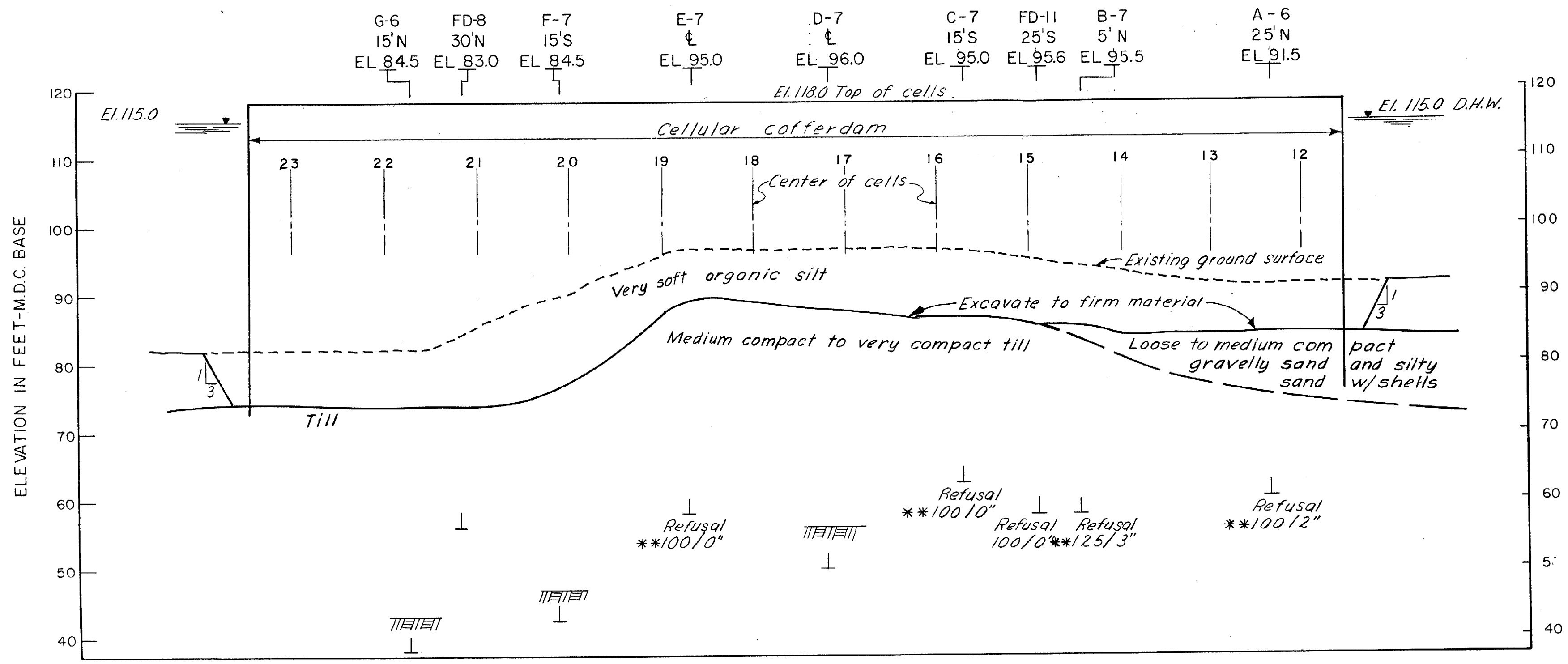
APPROVED DATE

CHIEF ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO. | DRAWING NUMBER

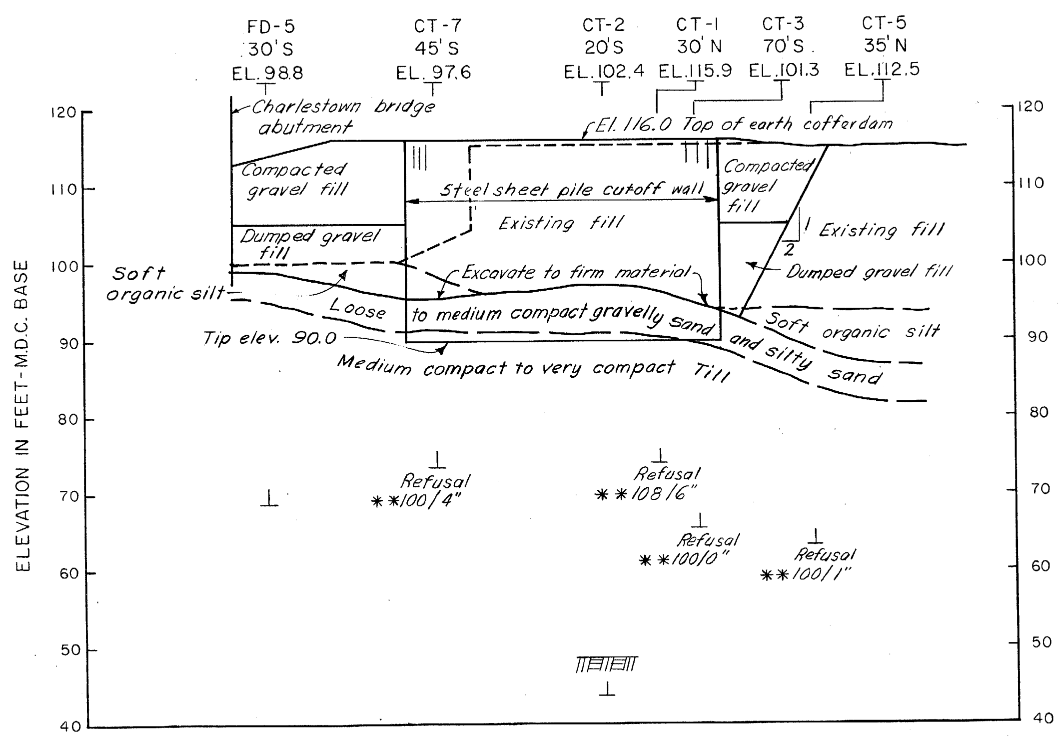
SHEET

PLATE 8-7



PROFILE 3-3

SCALES HORIZ. 1" = 40' VERT. 1" = 10'



PROFILE 4-4

SCALES HORIZ 1" = 40' VERT 1" = 10'

NOTES

1. For notes & legend see Plate 8-7
2. Profile locations shown on Plate 8-4

GRAPHIC SCALES

1" = 10' : 10' 0 10' 20'

1" = 40' : 40' 0 40' 80'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY

SUBMITTED:

ARCHITECT - ENGINEER

APPROVAL RECOMMENDED:

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

STAGE I COFFERDAM

SOIL PROFILES NO. 2

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

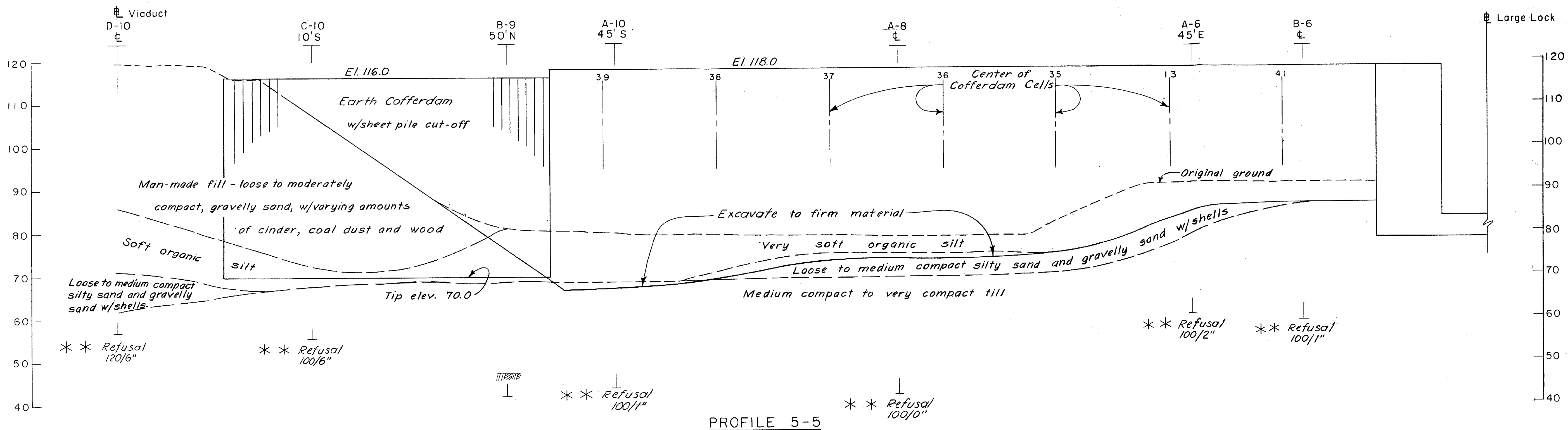
CHIEF ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO.

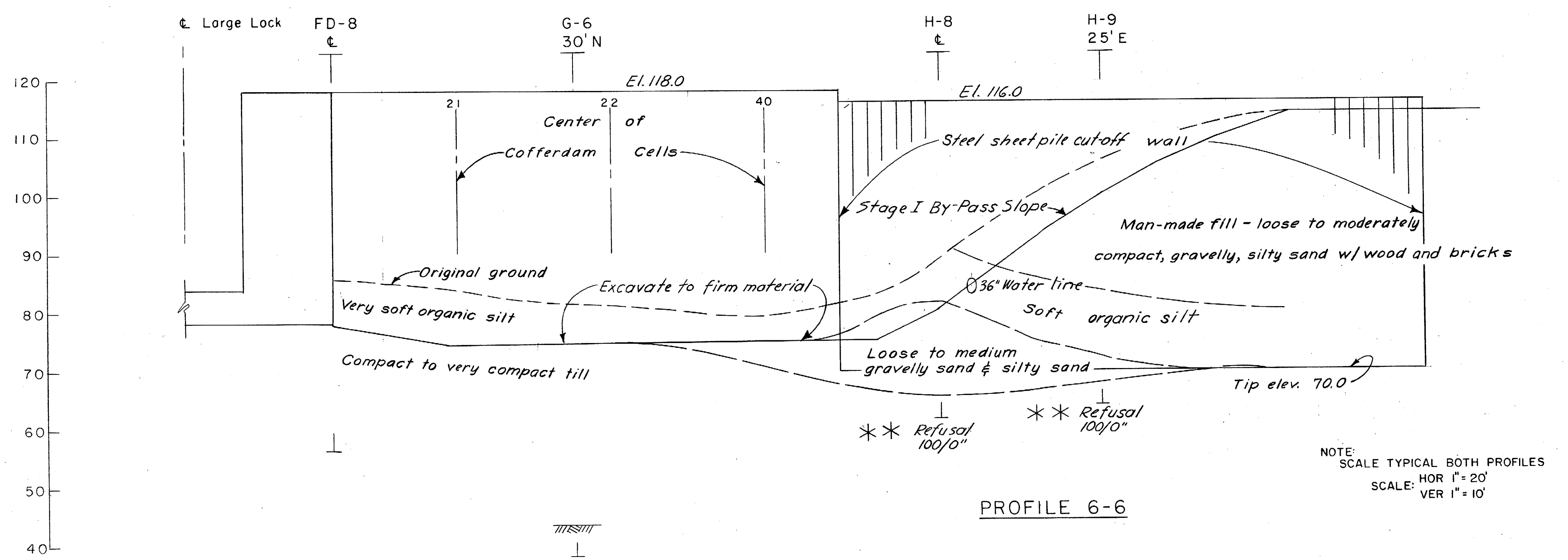
DRAWING NUMBER

SHEET

PLATE 8-8



PROFILE 5-5



PROFILE 6-6

NOTES:
1. For notes & legend, see Plate 8-7
2. Profile locations shown on Plate 8-5

NOTE:
SCALE TYPICAL BOTH PROFILES
SCALE: HOR 1" = 20'
VER 1" = 10'

GRAPHIC SCALES
1" = 20' 20' 0 20' 40'
1" = 10' 10' 0 10 20'

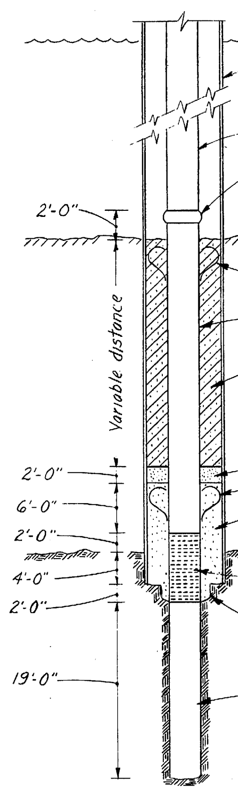
REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY J B M | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

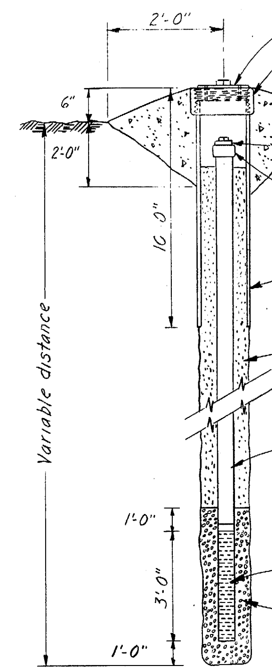
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STAGE 2 COFFERDAM
SOIL PROFILES
CHARLES RIVER BASIN MASSACHUSETTS
APPROVED DATE
CHIEF ENGINEERING DIVISION
SCALE: AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-9



RELIEF WELL

NOT TO SCALE

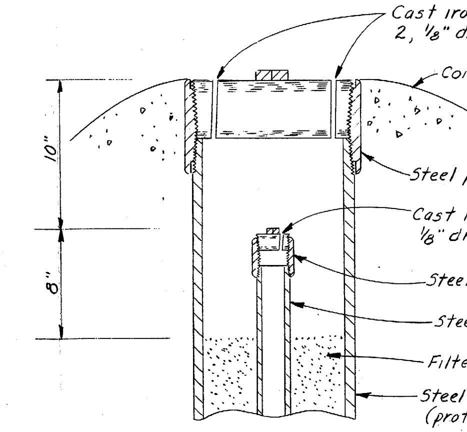


OBSERVATION WELL

NOT TO SCALE

NOTES:

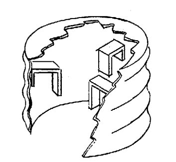
1. Location of relief wells, observation wells & piezometers are shown on Plates 8-4 & 8-5.
2. Piezometer will be of the pneumatic diaphragm type
3. Relief well covers will be installed immediately upon completion of wells.
4. Relief well cover Type II will be installed upon completion of wells located within foundation area of cofferdam gravel berm & Type I covers will be installed at all other relief wells.



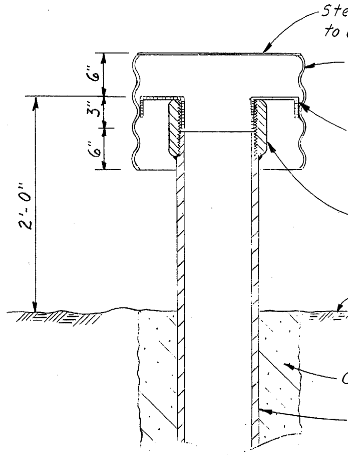
OBSERVATION WELL

DETAIL "C"

NOT TO SCALE



ISOMETRIC VIEW



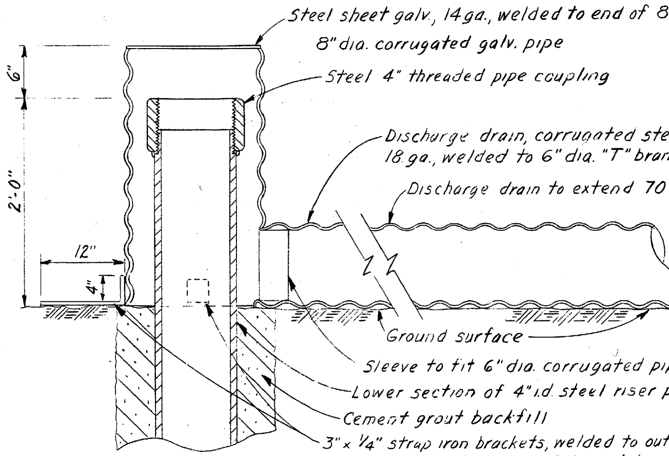
RELIEF WELL COVER-TYPE I

DETAIL "A"

NOT TO SCALE

Note

Type I, relief well covers shall be employed on wells located outside cofferdam gravel berm



RELIEF WELL COVER-TYPE II

DETAIL "B"

NOT TO SCALE

Note:

Type II, relief well covers shall be employed on wells located under the cofferdam gravel berm.

REVISION	DATE	DESCRIPTION	BY
⚠1	29/8/72	Note revised	

[redacted]

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY

SUBMITTED:

ARCHITECT - ENGINEER

APPROVAL RECOMMENDED:

REVIEWED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

RELIEF WELLS OBSERVATION WELLS AND PIEZOMETERS

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

CHIEF ENGINEERING DIVISION

SCALE: NONE | SPEC. NO.

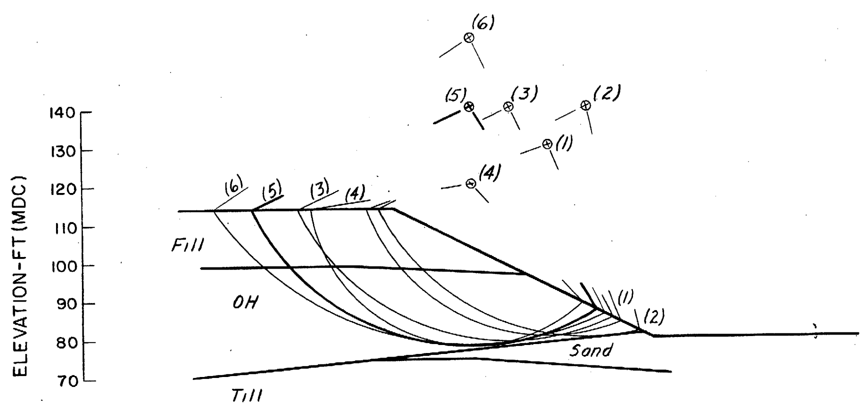
DRAWING NUMBER

SHEET

⚠1

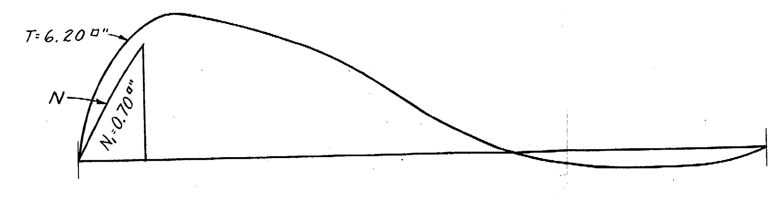
Rev. August '72 PLATE 8-10

ARC NO	FACTOR OF SAFETY
1	1.68
2	1.95
3	1.48
4	1.50
5	1.44
6	1.52



SECTION R-R
SCALE 1" = 20'

FIG 2-SUMMARY OF STABILITY ANALYSIS



(b) NORMAL AND TANGENTIAL FORCE DIAGRAM

DRIVING FORCE

$\Sigma T = 6.20 \times 10 \times 10 \times 62.4 = 38.6$ Kips

RESISTING FORCE

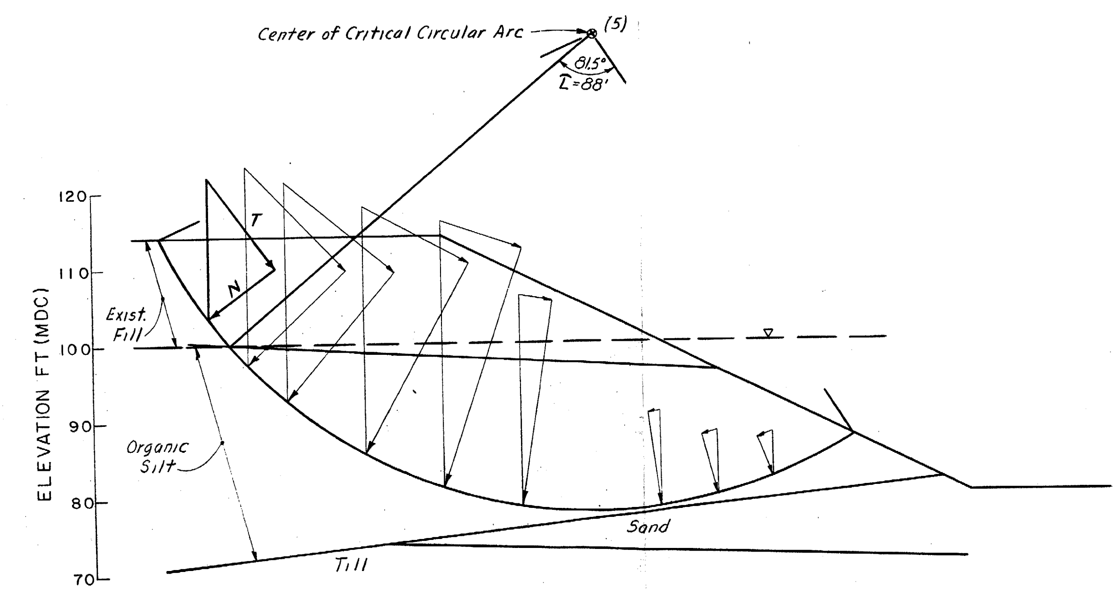
$C L + \Sigma N \tan \phi$

$= 600 \times 88 + 0.70 \times 10 \times 10 \times 62.4 \times .65$

$= 52.8 + 2.8 = 55.6$ Kips

SAFETY FACTOR

$\frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{55.6}{38.6} = 1.44$



(a) VECTOR DIAGRAM — CASE I — END OF CONSTRUCTION
SCALE 1" = 10'

FIG 3-CRITICAL CIRCULAR ARC ANALYSIS

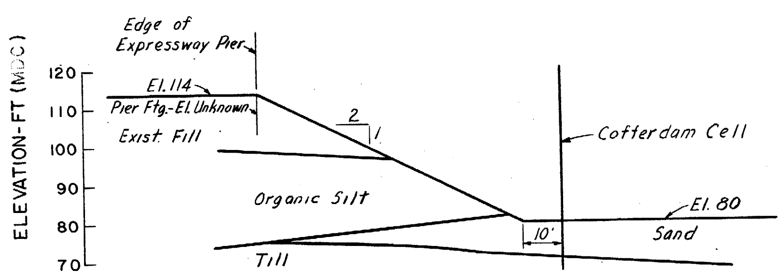
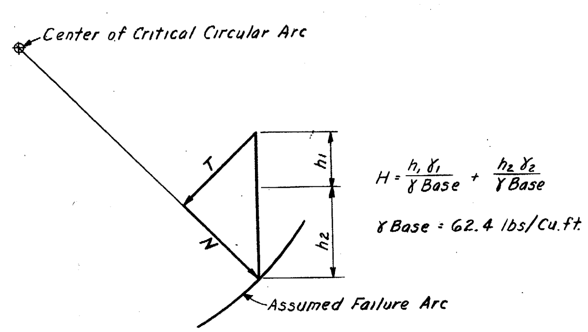


FIG 1-SECTION R-R
SCALE 1" = 20'



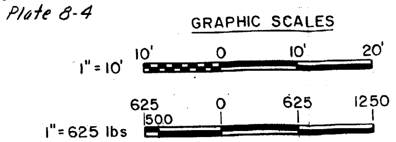
$H = \frac{h_1 \gamma_1}{\gamma \text{ Base}} + \frac{h_2 \gamma_2}{\gamma \text{ Base}}$

γ Base = 62.4 lbs/Cu.ft.

FIG 4-TYPICAL VECTOR DIAGRAM
NO SCALE

NOTES:
1. See Plate 8-12 for design values
2. Location of Setion R-R show on Plate 8-4

GRAPHIC SCALES



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY RDP | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

STABILITY ANALYSIS

CHARLESTOWN SLOPE

CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE

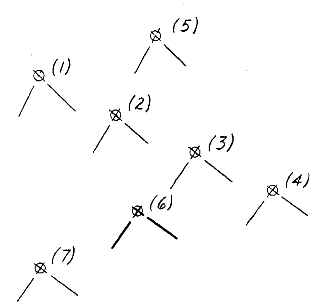
CHIEF ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO.

DRAWING NUMBER

SHEET

PLATE 8-11



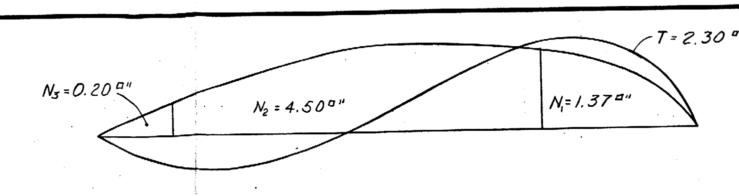
ARC NO	FACTOR OF SAFETY
1	1.65
2	1.61
3	1.59
4	2.08
5	1.67
6	1.53
7	1.80

VECTOR DIAGRAM - 1" = 20 × 62.4 = 1.25 KIPS
FORCE DIAGRAM - 1□" = 20 × 20 × 62.4 = 25.0 KIPS

DRIVING FORCE
$\Sigma T = 2.30$□" × 25.0 kips/sq.-in. = 57.5 kips

RESISTING FORCE = $\Sigma N \tan. \phi + c\bar{L}$
Fill = 1.57□" × 25.0 × .65 = 25.5 kips
Organic Silt = 4.50 × 25.0 × .466 + 99 × .10 = 52.5 + 9.9 = 62.4 kips
Total Resisting Force = 87.9 kips

SAFETY FACTOR
$SF = \frac{87.9}{57.5} = 1.53$



(b) NORMAL AND TANGENTIAL FORCE DIAGRAM

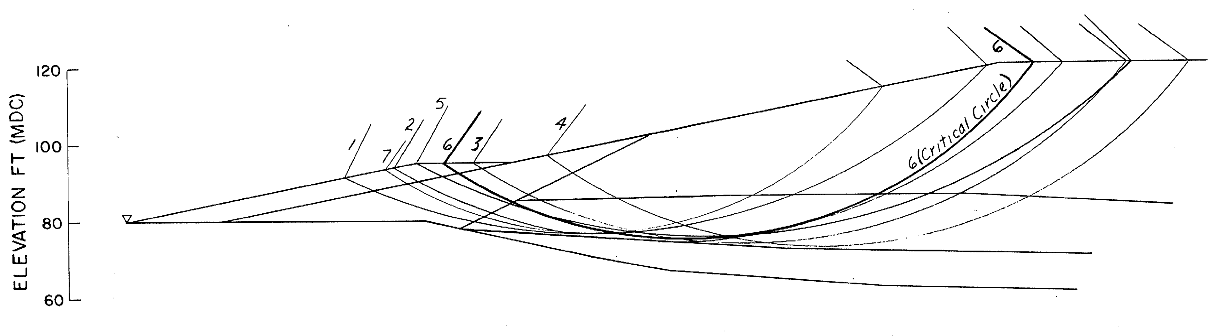
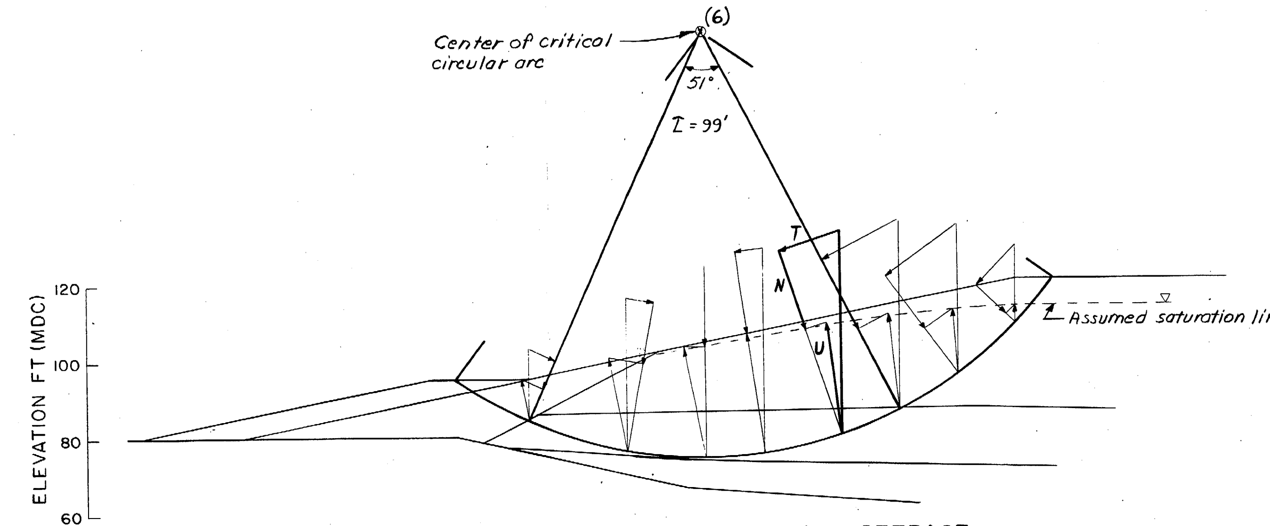


FIG. 2 — SUMMARY OF STABILITY ANALYSIS



(a) VECTOR DIAGRAM-CASE V-STEADY SEEPAGE
SCALE 1" = 20'

FIG. 3—CRITICAL CIRCULAR ARC ANALYSIS

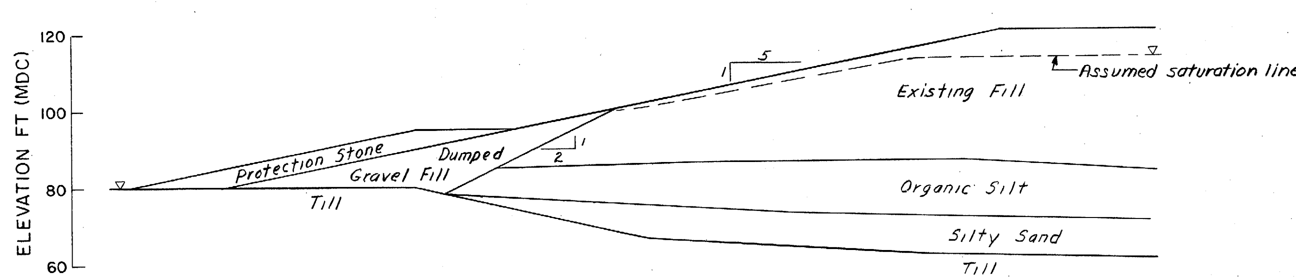
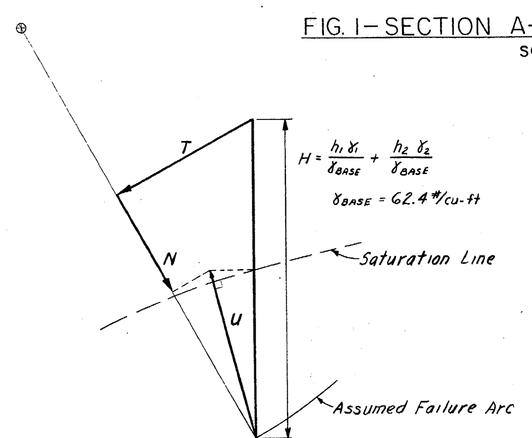


FIG. 1—SECTION A-A STAGE 2 COFFERDAM
SCALE 1" = 20'

MATERIAL	UNIT WEIGHT IN POUNDS PER CUBIC FOOT			SHEAR STRENGTH							
				Q-CONDITION		R-CONDITION		S-CONDITION		(R+S)/2	
	MOIST	SATURATED	SUBMERGED	⌀ degrees	C lbs/s.ft.	⌀ degrees	C lbs/s.ft.	⌀ degrees	C lbs/s.ft.	⌀	C
COMPACTED & DUMPED GRAVEL FILL	135	135	71	35	0	35	0	35	0	-	-
EXISTING SAND FILL	110	110	47.6	33	0	33	0	33	0	-	-
ORGANIC SILT	95	95	32.6	–	600	14	200	36	0	25	100
SILTY SAND	110	110	47.2	33	0	33	0	33	0	-	-

FIG. 6 — DESIGN VALUES



$H = \frac{h_1 \gamma_1}{\gamma_{BASE}} + \frac{h_2 \gamma_2}{\gamma_{BASE}}$

γ_{BASE} = 62.4 #/cu.ft

FIG. 4—TYPICAL VECTOR DIAGRAM
NO SCALE

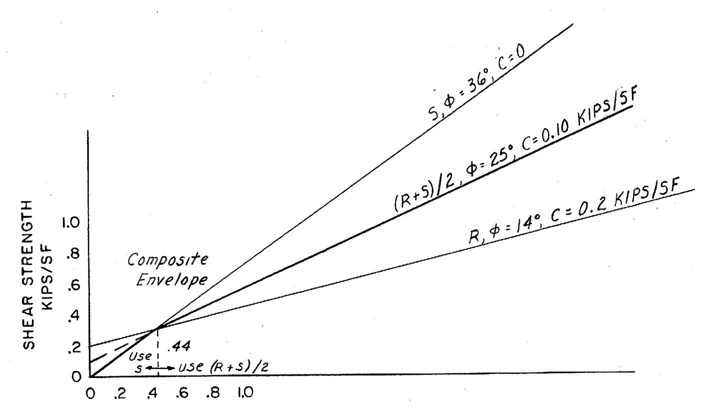
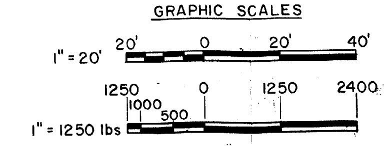


FIG. 5—COMPOSITE STRENGTH ENVELOPE-ORGANIC SILT FOR CASE V STEADY SEEPAGE ANALYSIS

NOTE
1. Location of Section A-A shown on Plate 8-5

GRAPHIC SCALES



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

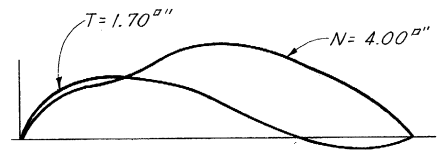
DES. BY | DR. BY RDP | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STABILITY ANALYSIS
BOSTON SLOPE
CHARLES RIVER BASIN MASSACHUSETTS

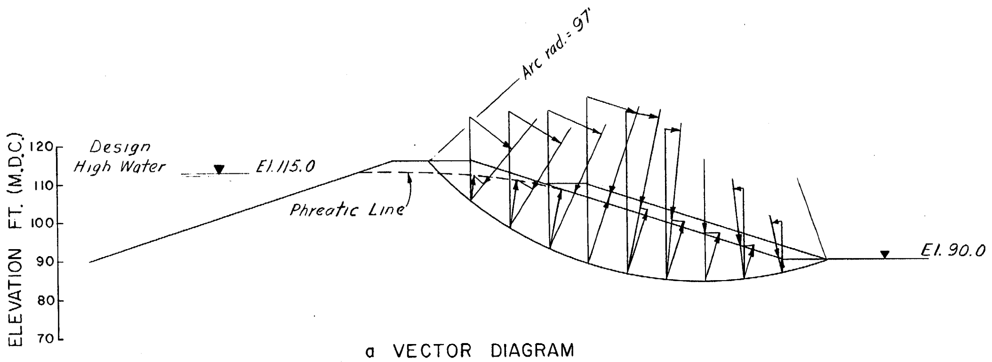
APPROVED DATE
CHIEF ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

DRIVING FORCE
$\Sigma T = 1.70^{\square''} \times 25.0\ Kips/^{\square''} = 42.5\ Kips$
RESISTING FORCE
$\Sigma N\ Tan\ \phi = 4.00^{\square''} \times 25\ Kips/^{\square''} \times .7 = 70.0\ Kips$
FACTOR of SAFETY = 70.0 Kips/42.5 Kips = 1.65



b TANGENTIAL AND NORMAL FORCE DIAGRAM

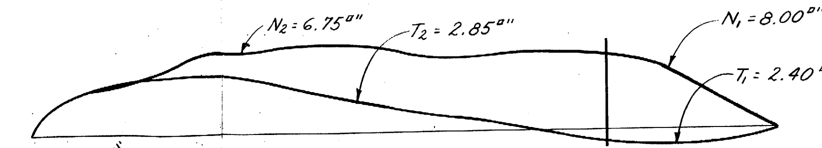


a VECTOR DIAGRAM

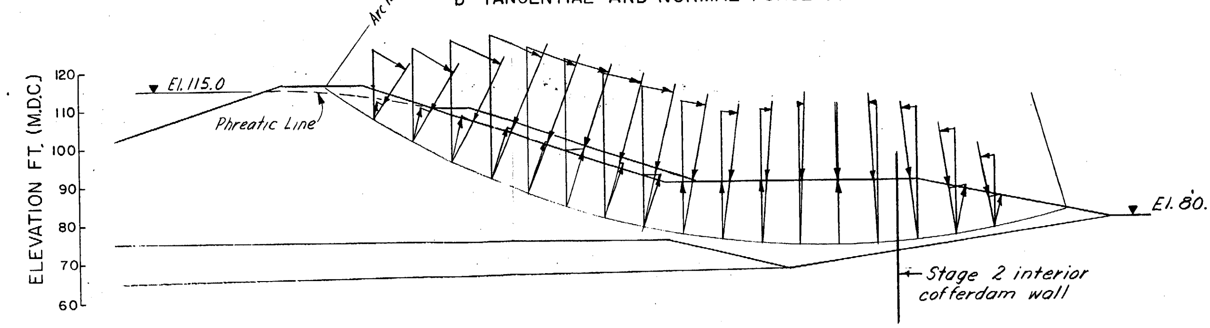
FIG 4 - CIRCULAR ARC NO 3

CONDITION 1 - W/1on5 slope at toe
DRIVING FORCE Summation of tangential forces
$\Sigma T_1 = 2.40 \times 25.0 = 60.0$ Kips
RESISTING FORCE = Summation N Tan ϕ + CL
ΣN_1 Tan ϕ = 8.00×25.0×0.70 = 140 Kips
FACTOR of SAFETY = Resisting Force/Driving Force
F. S. = 140/60.0 = 2.33

CONDITION 2 - W/Stage 2 interior cofferdam wall in place and gravel fill removed from toe area behind Stage 2 Interior Cofferdam wall.
DRIVING FORCE
ΣT_2 = 2.85×25.0 = 71.2 Kips
RESISTING FORCE
ΣN_2 Tan ϕ = 6.75×25.0×0.70 = 118.0 Kips
F.S. = 118.0/71.2 = 1.66



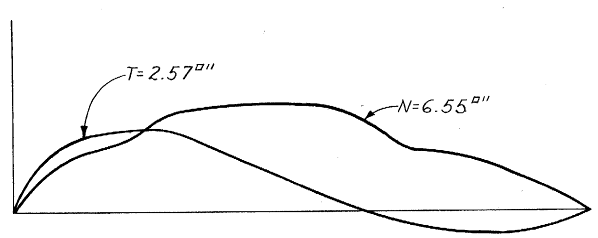
b TANGENTIAL AND NORMAL FORCE DIAGRAM



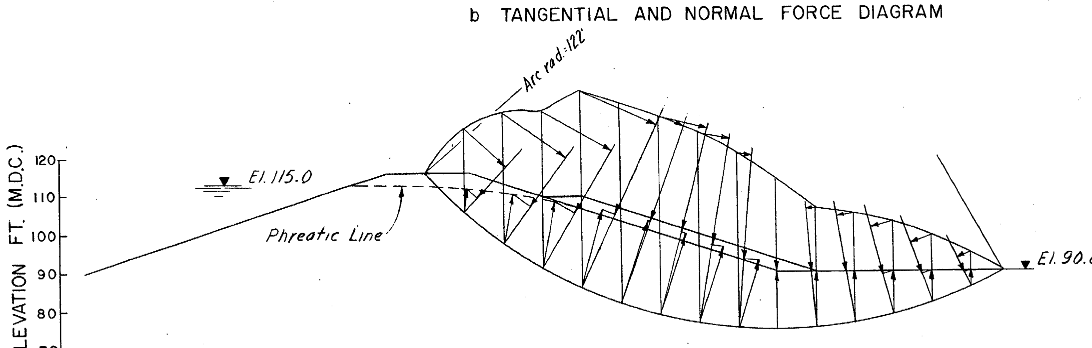
a VECTOR DIAGRAM

FIG 2 - CIRCULAR ARC NO 1

DRIVING FORCE
$\Sigma T = 2.57^{\square''} \times 25.0\ Kips/^{\square''} = 64.2\ Kips$
RESISTING FORCE
$\Sigma N\ Tan\ \phi = 6.55^{\square''} \times 25.0\ Kips/^{\square''} \times .7 = 114.5\ Kips$
FACTOR of SAFETY = 114.5 Kips/64.2 Kips = 1.78



b TANGENTIAL AND NORMAL FORCE DIAGRAM



a VECTOR DIAGRAM

FIG 3 - CIRCULAR ARC NO 2

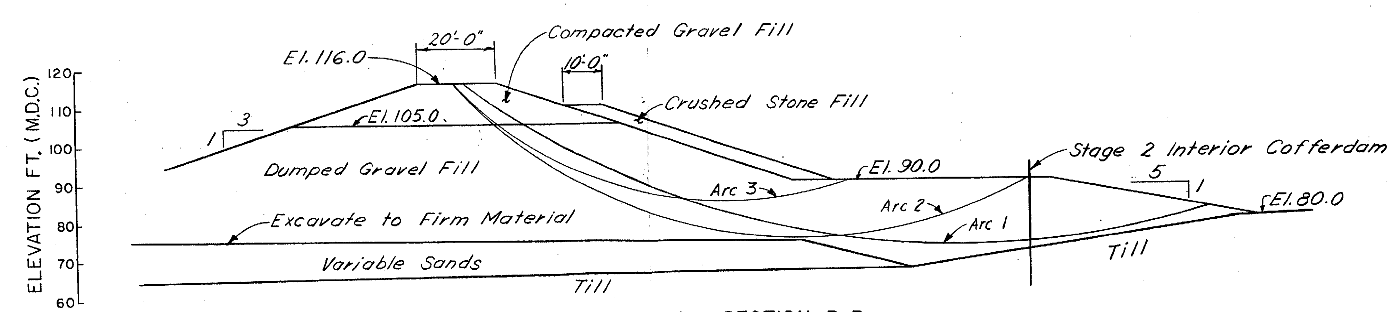
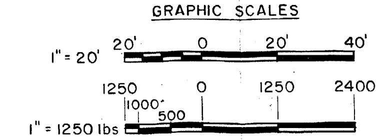


FIG 1 SECTION B-B

γsat. = 135 Lbs/Cu.ft.
ϕ = 35°
C = 0
γbase = 62.5 Lbs/Cu.ft.

NOTES
1. Section B-B location shown on Plate 8-5
2. See Plate 8-12 for design values.
3. VECTOR DIAGRAM
1 inch = 20 x 62.5 x 1/1000 = 1.25 Kips
4. FORCE DIAGRAM
1 sq. inch = 20 x 20 x 62.5 x 1/1000 = 25.0 Kips

GRAPHIC SCALES



STABILITY ANALYSIS - SECTION B-B STAGE 2 COFFERDAM

CASE V - STEADY SEEPAGE

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY | DR. BY A.H. | CK. BY
SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STABILITY ANALYSIS
STAGE 2 - EARTH DIKE COFFERDAM
CHARLES RIVER BASIN MASSACHUSETTS
APPROVED DATE
CHIEF ENGINEERING DIVISION
SCALE: AS SHOWN | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-13

LOADING CONDITIONS

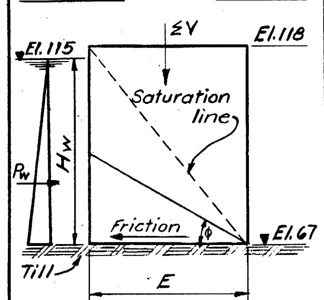
LC1 MAX. WATER ELEV. OUTBOARD SIDE. CELL FILL SATURATED FROM TOP OF CELL OUTBOARD TO BOTTOM OF CELL INBOARD.

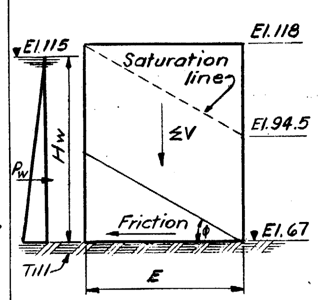
LC2 MAX. WATER ELEV. OUTBOARD SIDE. CELL FILL SATURATED FROM TOP OF OUTBOARD ON A 1 ON 2 SLOPE TO INBOARD SIDE.

LC4 MAX. WATER ELEV. OUTBOARD SIDE. CELL FILL SATURATED TO TOP OF SURCHARGE.

CASE 1 WEIGHT SATURATED CELL FILL IS 134.2 LBS/CU FT. WEIGHT SUBMERGED CELL FILL IS 70.0 LBS/CU.FT.

CASE 2 WEIGHT SATURATED CELL FILL IS 119.2 LBS/CU.FT. WEIGHT SUBMERGED CELL FILL IS 55.0 LBS/CU.FT.

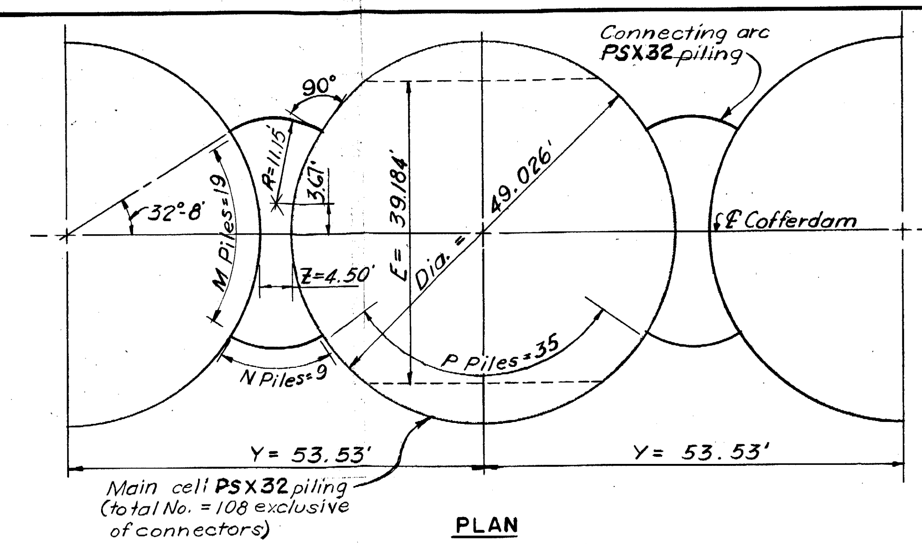




HORIZONTAL SHEAR ANALYSIS	EQUATION *	LOADING CONDITION NO. 1		LOADING CONDITION NO. 2	
		CASE 1	CASE 2	CASE 1	CASE 2
TILTING RESISTANCE OF CELL FILL	$M_R = \Sigma(F_i \times y_i)$	1057.25 FT-K	890.54	906.62	739.91
APPLIED FORCES AND OVERTURNING MOMENTS	$P_W = \frac{1}{2} \gamma_w H_w^2$	73.96 K	73.96	73.96	73.96
	$M_o = P_w \times \frac{H_w}{3}$	1183.33 FT-K	1183.33	1183.33	1183.33
TILTING RESISTANCE OF INTERLOCK FRICTION	P = CELL PRESS. ON INBOARD SIDE	58.12 K	51.62	74.32	67.82
	$M_F = .3 \times P \times E$	683.18 FT-K	606.82	873.59	797.23
SAFETY FACTOR AGAINST TILTING	$N_t = \frac{M_R \times M_F}{M_o}$	1.47	1.27	1.50	1.30
SLIDING FACTOR OF SAFETY	$SSF = \frac{\tan\phi \times \Sigma V}{P_w}$	1.59	1.36	1.32	1.09
PILE INTERLOCK TENSION AT BASE OF CELL	$t_{max} = \frac{P \times L \times \sec\theta}{12}$	7.19 KLI	6.39	10.90	10.10
VERTICAL SHEAR ANALYSIS					
DRIVING SHEAR	$Q = \frac{3 M_o}{2 E}$	45.30K	45.30	45.30	45.30
CENTER SHEAR RESISTANCE CELL FILL AND FRICTIONAL RESISTANCE OF SHEET PILE INTERLOCK	$S_n = P_t \times \tan\phi$	53.20K	46.44	43.30	36.55
	$S_t = \frac{T\ r\ f\ n}{Y}$	29.77 K	25.56	31.44	28.23
SAFETY FACTOR AGAINST FAILURE	$G_s = \frac{S_n \times S_t}{Q}$	1.81	1.59	1.65	1.43

* ALPHABETIC SYMBOLIC FORMULATION IN ACCORDANCE WITH EM 1110-2-2906 AND EC 1110-2-114

△1



PLAN
CELLULAR COFFERDAM
DESIGN SECTION
SCALE 1" = 10'-0"

CELLULAR COFFERDAM DESIGN DATA

H ____ = HEIGHT OF CELL ____________ = ____ 51.0 __ FEET
D ____ = DIAMETER OF CELL ____________ = ____ 49.026 FEET
E ____ = EFFECTIVE WIDTH OF CELL ____________ = ____ 39.184 FEET
Y ____ = ℄ TO ℄ DISTANCE OF CELLS ____________ = ____ 53.53 __ FEET
Ka ____ = COEF. ACTIVE EARTH PRESS ____________ = ____ 0.333
γ_W ____ = UNIT WEIGHT OF WATER ____________ = ____ 64.2 LBS./CU.FT.
ϕ ____ = ANGLE OF REPOSE CELL FILL ____________ = ____ 30.0 DEGREES
$\tan\phi$ ____ = COEF. SLIDING FRICTION ____________ = ____ 0.577
t_{max} ____ = MAX. INTERLOCK TENSION __(1) ____________ = ____ 14.0 K/LIN. IN (ALL)
N_t, G_s ____ = FACTOR OF SAFETY AGAINST TILTING ____________ = ____ 1.25 MINIMUM
SSF ____ = FACTOR OF SAFETY AGAINST SLIDING ____________ = ____ 1.0 MINIMUM
H_w ____ = HEIGHT OF WATER OUTBOARD SIDE
Pw ____ = APPLIED HORIZONTAL WATER FORCE
ΣV ____ = NET WEIGHT OF CELL FILL

(1) NOTE: USE PSX32 STEEL SHEET PILING FOR MAIN CELL, CONNECTING TEES AND CONNECTING ARCS

GRAPHIC SCALES
1" = 10' 10' 0 10' 20'

REVISION	DATE	DESCRIPTION	BY
△1	8/21/72	Loading conditions No. 4 deleted	

[redacted]

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY P. L. | DR. BY A. Z. | CK. BY

SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH

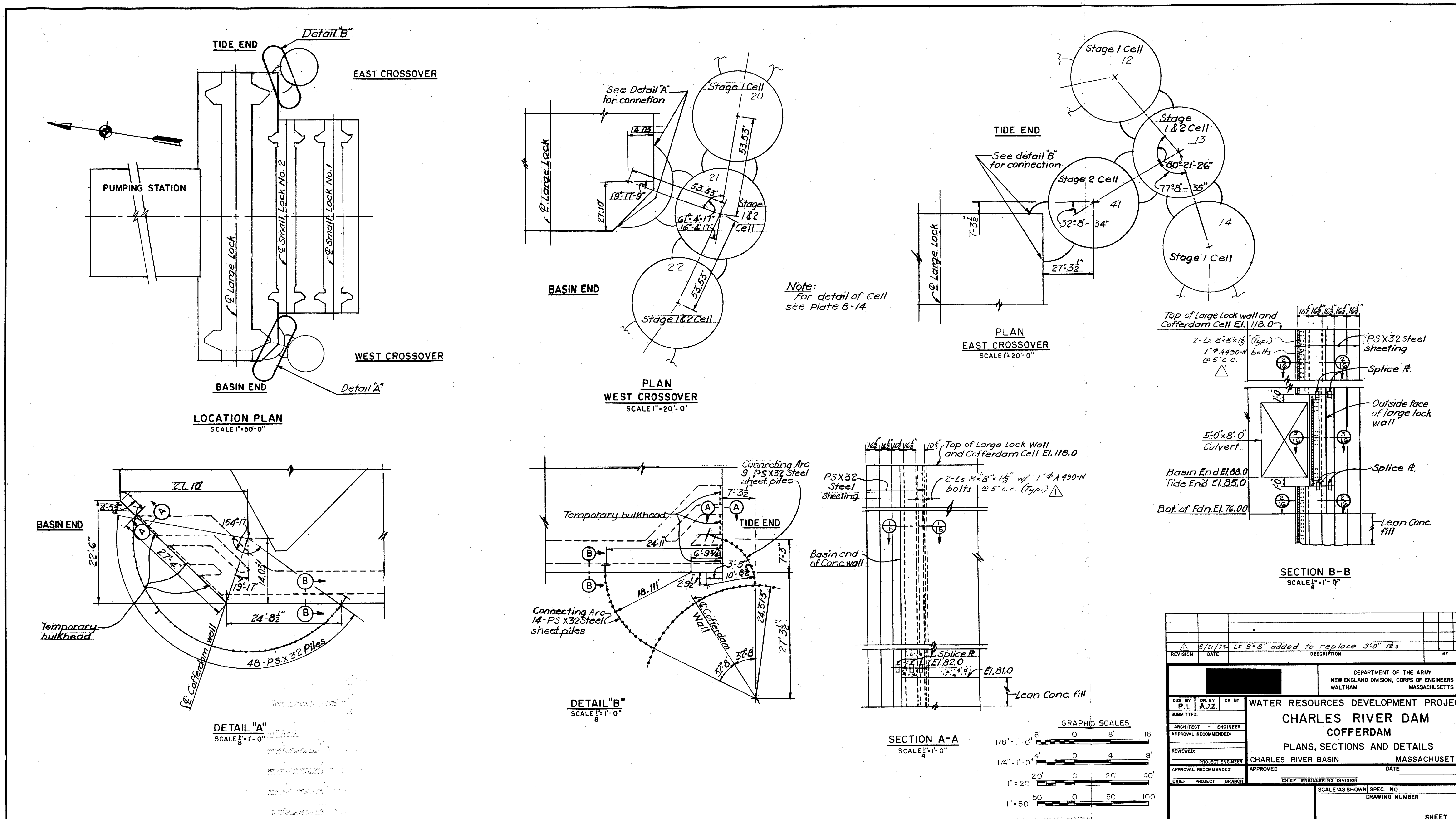
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
STRUCTURAL
STABILITY ANALYSIS
CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE
CHIEF ENGINEERING DIVISION

SCALE: 1" = 10' | SPEC. NO.
DRAWING NUMBER
SHEET

△1

Rev. August '72 PLATE 8-14



REVISION	DATE	DESCRIPTION	BY
1	8/21/72	Ls 8"x8" added to replace 3'-0" Pℓs	

[redacted]

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY P.L. DR. BY A.J.Z. CK. BY

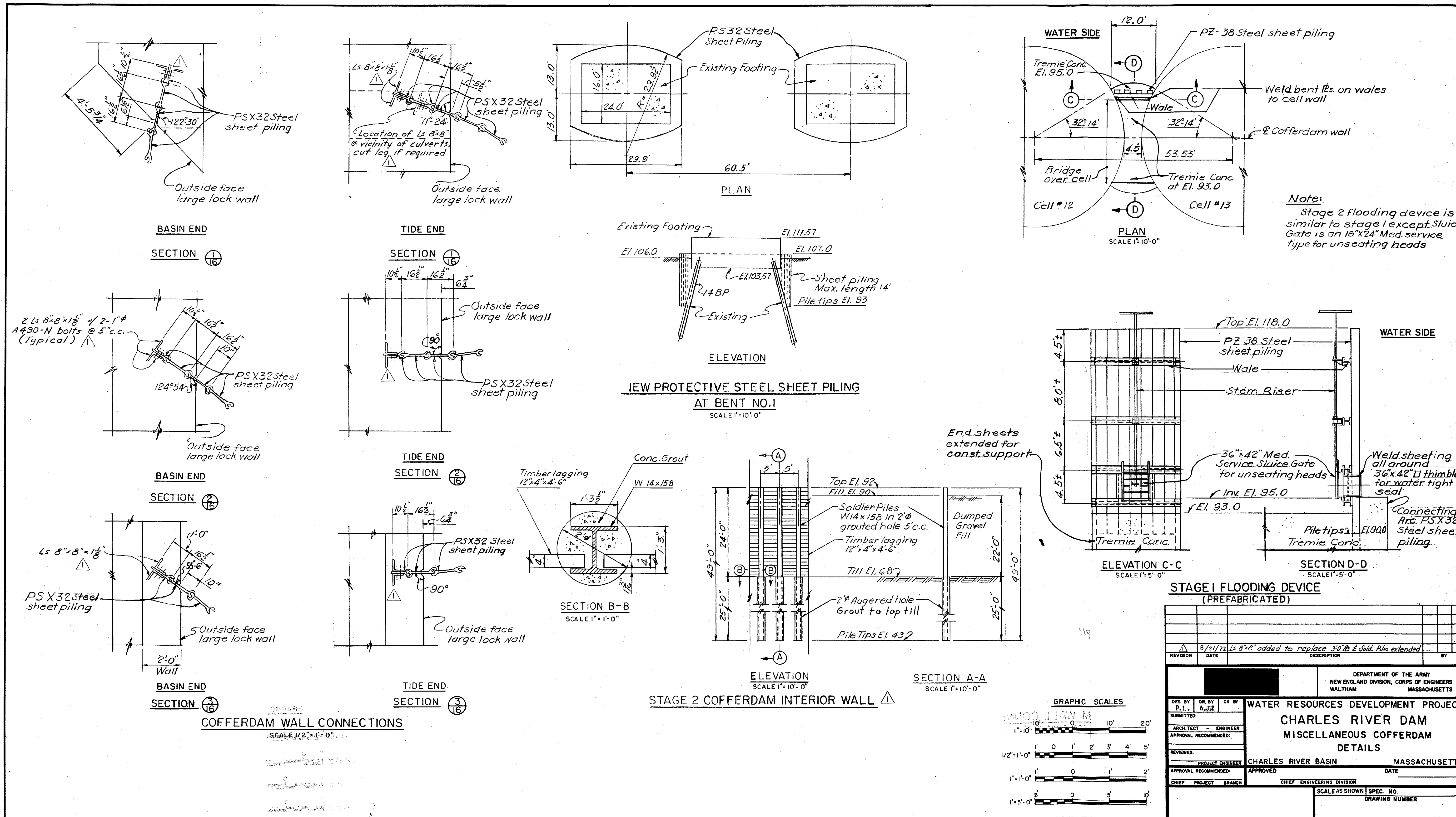
WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM
COFFERDAM
PLANS, SECTIONS AND DETAILS

CHARLES RIVER BASIN MASSACHUSETTS

SUBMITTED:
ARCHITECT - ENGINEER
APPROVAL RECOMMENDED:
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF PROJECT BRANCH
APPROVED DATE
CHIEF ENGINEERING DIVISION
SCALE AS SHOWN SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 8-15



REVISION	DATE	DESCRIPTION	BY
1	8/21/72	Ls 8"x8" added to replace 3'-0" Pls. & Sold. Piles extended	

[redacted]

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASSACHUSETTS

DES. BY P.L. | DR. BY A.J.Z | CK. BY

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

MISCELLANEOUS COFFERDAM DETAILS

CHARLES RIVER BASIN MASSACHUSETTS

SCALE AS SHOWN

Rev. August '72 PLATE 8-16

APPENDIX A

STRUCTURAL COMPUTATIONS

CHARLES RIVER DAM

COFFERDAMS
DESIGN MEMORANDUM NO. 8

APPENDIX A

INDEX

Rev. Aug 72

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

PAGE 1.1

SUBJECT Charles River
COMPUTATION Cellular Co.-Ferdam Stability Analysis
COMPUTED BY FRL CHECKED BY ______ DATE 18 Apr. 72

SUMMARY OF DESIGN COMPUTATIONS

WATER ELEV OUTBOARD = 115 FOR EXTREME COND = 117
TOP CELL ELEV 118 BOT CELL ELEV = 67

ITEM	LOAD. COND. 1		LOAD. COND. 2		~~LOAD COND 4~~		Extreme Cond, Case 2		
	CASE 1	CASE 2	CASE 1	CASE 2	~~CASE 1~~	~~CASE 2~~	LC 1 (3)	LC 2 (3)	~~LC 4 (3)~~
SAFETY FACTOR TILTING, N_t Min = 1.25	1.47	1.27	1.50	1.30	~~1.69~~	~~1.49~~	(2) 1.12	(2) 1.16	~~1.34~~
SAFETY FACTOR SLIDING, SSF Min = 1.0	1.59	1.36	1.32	1.09	~~1.15~~	~~(1) .92~~	1.25	(1) .99	~~(1) .83~~
INTERLOCK STRESS, K/Lin in All = 14.0	7.19	6.39	10.90	10.10	~~13.27~~	~~12.46~~	6.39	10.37	~~12.73~~
SAFETY FACTOR VERT SHEAR Min. = 1.25	1.81	1.59	1.65	1.43	~~1.56~~ VOID 21 Aug. 72	~~1.34~~	1.41	1.26	~~(2) 1.18~~ VOID 21 Aug 72
PAGE NO.	3	4	5	6	7	8	9	10	11

(1) SF < 1.0 but still permissible
(2) SF < 1.25 but still permissible
(3) Extreme condition shown only to demonstrate the extent of reduction in the SF

Rev. August '72

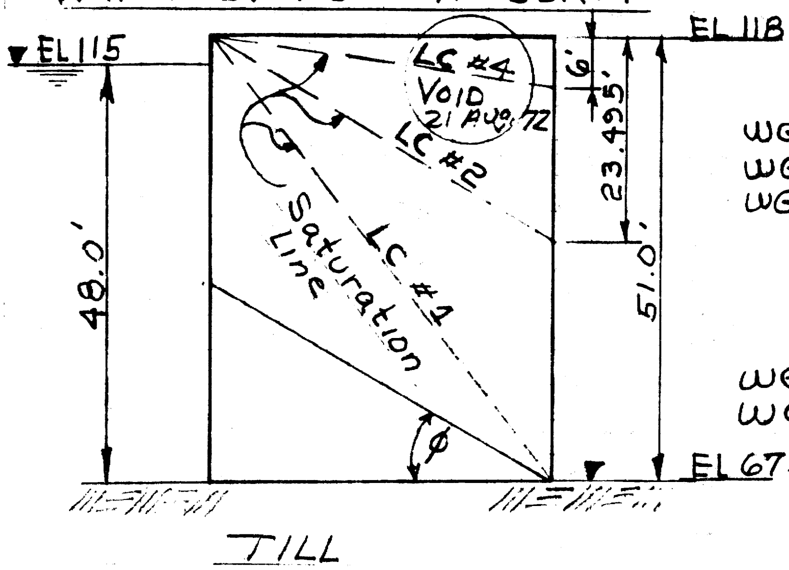
NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Charles River
COMPUTATION Cellular Cofferdam Stability Analysis
COMPUTED BY PRL CHECKED BY DATE 18 Apr 72

CELLULAR COFFERDAM
DESIGN ASSUMPTIONS

H = 51 Ft D = 49.026 Ft.
WAT ELEV 115 NO BERM



CASE 1

WGT SAT EA = 134.2 #/ft^3
WGT SUB EA = 70.0 #/ft^3
WGT WAT = 64.2 #/ft^3

CASE 2

WGT SAT EA = 119.2 #/ft^3
WGT SUB EA = 55.0 #/ft^3
WGT WAT = 64.2 #/ft^3

Specifications:

1. PSX32 Steel sheet piling for MAIN CELL
2. PSX32 Steel sheet piling for Connecting Arcs
3. Diameter of cell D = 49.026'
4. ℄ to ℄ Dist of cells, Y = 53.53'
5. Radius connecting arcs R = 11.15'
6. Effective width cell, E' = 39.184'
7. No. Piles in cell = 108
   M-Piles = 19
   P-Piles = 35

8. No. Piles in connecting arc = 9
9. Design is prepared in accordance with EC 1110-2-114
10. Layout for PSX32 Provided by US Steel Co.
    Ref: USS - Steel Sheet Piling Specifications
    USS - Steel Sheet Piling Design Manual

* See Plate 8-14 For Cell Layout

Rev. Aug.'72

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114 16 NOV 70

TITLE: C CHARLES RIVER 18 APRIL 1972

CASE 1 LOADING CONDITION 1

:

HT CELL (H)= C 51.0 :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184 :TANP= .577:
Y-DIST (Y)= 53.53 :HT WAT (H1)= 48.0:
DEP SAT LINE = 51.0:
SAT UNIT WT (W2)= .1342 :SUB UNIT WT (W3)= .07:
WT WAT (W1)= .0642 :K ACTIVE (K1)= .333:
K AT REST (K2)= .6 :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=204.035006 SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=1057.24575

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=58.117524
M(F)=.3(P)(E)=683.18312

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.47078363

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.5918165

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=7.18790525

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=53.1950408
S(T)=.3(T)(N)/(Y)=28.771639

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.80945321

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION1

:

HT CELL (H)= C 51.0   :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184 :TANP= .577:
Y-DIST (Y)= 53.53   :HT WAT (H1)= 48.0:
DEP SAT LINE = 51.0:
SAT UNIT WT (W2)= 0.1192:SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642   :K ACTIVE (K1)= .333:
K AT REST (K2)= .6   :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=174.059246   SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=890.542383

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=51.621527
M(F)=.3(P)(E)=606.82137

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.26537668

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.3579551

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=6.38448808

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=46.4415443
S(T)=.3(T)(N)/(Y)=25.555733

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.58937394

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 1   LOADING CONDITION 2

:

HT CELL (H)= C   51.0   :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184   :TANP= .577:
Y-DIST (Y)= 53.53   :HT WAT (H1)= 48.0:
DEP SAT LINE = 23.495:
SAT UNIT WT (W2)= .1342   :SUB UNIT WT (W3)= .07:
WT WAT (W1)= .0642   :K ACTIVE (K1)= .333:
K AT REST (K2)= .6   :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=169.439041   SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=906.617286

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=74.3152545
M(F)=.3(P)(E)=873.59068

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.50439974

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.32190971

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=10.9024698

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=43.2988001
S(T)=.3(T)(N)/(Y)=31.440578

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.64990711

6/11

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION 2

:

HT CELL (H)= C 51.0 :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184 :TANP= .577:
Y-DIST (Y)= 53.53 :HT WAT (H1)= 48.0:
DEP SAT LINE = 23.495:
SAT UNIT WT (W2)= .1192 :SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642 :K ACTIVE (K1)= .333:
K AT REST (K2)= .6 :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=139.463282   SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=739.913893

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=67.8192575
M(F)=.3(P)(E)=797.22894

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.29899277

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.08804834

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=10.0990528

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=36.5453024
S(T)=.3(T)(N)/(Y)=28.224673

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.42982783

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 1   LOADING CONDITION 4

:

HT CELL (H)= C   51.0   :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184   :TANP= .577:
Y-DIST (Y)= 53.53   :HT WAT (H1)= 48.0:
DEP SAT LINE = 6.0:
SAT UNIT WT (W2)= .1342   :SUB UNIT WT (W3)= .07:
WT WAT (W1)= .0642   :K ACTIVE (K1)= .333:
K AT REST (K2)= .6   :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=147.433718   SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=810.807604

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=101.474191
M(F)=.3(P)(E)=1192.84940

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.69322974

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.15023114

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=13.2651783

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=34.8168839
S(T)=.3(T)(N)/(Y)=35.915623

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.56145353

9/11

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION 4

:

```
HT CELL (H)=  C     51.0     :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184     :TANP= .577:
Y-DIST (Y)= 53.53          :HT WAT (H1)= 48.0:
DEP SAT LINE = 6.0:
SAT UNIT WT (W2)= .1192     :SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642         :K ACTIVE (K1)= .333:
K AT REST (K2)= .6         :NUMF= 20:
```

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=117.457958   SUMH=73.958400

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=644.104208

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=73.958400
M(O)=P(WAT) X H/3=1183.33440

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=94.9781948
M(F)=.3(P)(E)=1116.48767

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.48782277

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=.91636977

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=12.4617617

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=45.299143

SHEAR RESISTANCE
S(N)=P(T) X TANP=28.0633872
S(T)=.3(T)(N)/(Y)=32.699718

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.34137428

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION 1   EXTREME WAT ELEV 117

:

HT CELL (H)= C 51.0 :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184 :TANP= .577:
Y-DIST (Y)= 53.53 :HT WAT (H1)= 50.0:
DEP SAT LINE = 51.0:
SAT UNIT WT (W2)= .1192 :SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642 :K ACTIVE (K1)= .333:
K AT REST (K2)= .6 :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=174.059246   SUMH=80.250000

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=890.542383

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=80.250000
M(O)=P(WAT) X H/3=1337.50000

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=51.621527
M(F)=.3(P)(E)=606.82137

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.11952430

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=1.2514914

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=6.38448808

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=51.200745

SHEAR RESISTANCE
S(N)=P(T) X TANP=46.4415443
S(T)=.3(T)(N)/(Y)=25.555733

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.40617636

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION 2   EXTREME WAT ELEV
:

HT CELL (H)= C51.0   :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184   :TANP= .577:
Y-DIST (Y)= 53.53   :HT WAT (H1)= 50.0:
DEP SAT LINE = 21.495:
SAT UNIT WT (W2)= .1192   :SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642   :K ACTIVE (K1)= .333:
K AT REST (K2)= .6   :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=136.947669   SUMH=80.250000

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=728.961082

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=80.250000
M(O)=P(WAT) X H/3=1337.50000

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=70.2605055
M(F)=.3(P)(E)=825.92630

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.16253262

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=.98465801

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=10.3691538

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=51.200745

SHEAR RESISTANCE
S(N)=P(T) X TANP=35.6617614
S(T)=.3(T)(N)/(Y)=28.626923

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.25562010

CELLULAR COFFER DAM ON ROCK

REF: EC 1110-2-114   16 NOV 70

TITLE: C   CHARLES RIVER   18 APRIL 1972

CASE 2   LOADING CONDITION 4   EXTREME WAT ELEV 117

:

HT CELL (H)= C51.0   :DIAM CELL= 49.026:
EFF WIDTH CELL (E)= 39.184   :TANP= .577:
Y-DIST (Y)= 53.53   :HT WAT (H1)= 50.0:
DEP SAT LINE = 4.0:
SAT UNIT WT (W2)= .1192   :SUB UNIT WT (W3)= .055:
WT WAT (W1)= .0642   :K ACTIVE (K1)= .333:
K AT REST (K2)= .6   :NUMF= 20:

ALL UNITS ARE IN FT KIPS EXCEPT INTERLOCK STRESS IN KSI

SUMV=114.942345   SUMH=80.250000

'HORIZONTAL SHEAR'

TILTING RESISTANCE OF CELL FILL
M(R)=(W)(F)=633.151398

APPLIED FORCES AND OVERTURNING MOMENTS
P(WAT)=.5(W1)(H1)(H1)=80.250000
M(O)=P(WAT) X H/3=1337.50000

TILTING RESISTANCE INTERLOCK FRICTION
P=.5(W2)(H)(H)(K1)=98.9177636
M(F)=.3(P)(E)=1162.79810

SAFETY FACTOR AGAINST TILTING
N(T)=(M(R)+M(F))/M(O)=1.34276597

SAFETY FACTOR AGAINST SLIDING
SSF=TANP X SUMV/SUMH=.82643904

PILE INTERLOCK TENSION
MAX INTERLOCK STRESS=(P)(L)SEC θ /12=12.7318625

'VERTICAL SHEAR'

DRIVING SHEAR
Q=3M/2E=51.200745

SHEAR RESISTANCE
S(N)=P(T) X TANP=26.9854248
S(T)=.3(T)(N)/(Y)=33.348850

SAFETY FACTOR
G(S)=S(N)+S(T))/Q=1.17838666

CELLULAR COFFERDAM DESIGN
ON A ROCK FOUNDATION

BY

W. J. HOLTHAM
&
P. R. LALIBERTE

ADP EQUIP: MATHATRON CSIII

A-12

CELLULAR COFFERDAM DESIGN
ON A ROCK FOUNDATION

BY

W. J. HOLTHAM
&
P. R. LALIBERTE

ADP EQUIP: MATHATRON CSIII

A-12

CELLULAR COFFERDAM ON ROCK FOUNDATION

GLOSSARY

REF: EC 1110-2-114
USS- STEEL SHEET PILING
DESIGN MANUAL

ITEM	REGISTER	DESCRIPTION
H	S0	HEIGHT CELL FILLED WITH EARTH
D	S1	ACTUAL DIAMETER OF CELL
E	S2	EFFECTIVE WIDTH OF CELL
TAN Ø	S3	COEFFICIENT FRICTION CELL FILL & ROCK
Y-DIST	S4	CENTERLINE DIST OF 2 ADJOINING CELLS
H(WAT)	S5	HEIGHT OF WATER OUTBOARD
γ(SAT)	S6	UNIT WEIGHT SATURATED EARTH
γ(SUB)	S7	" " SUBMERGED "
γ(WAT)	S913	" " WATER
DS	S950	DEPTH FROM TOP CELL TO SATURATION LINE
K(A)	S914	COEFFICINET ACTIVE EARTH PRESSURE
K(P)	S916	" PASSIVE " "
NUMF	S901	TOT. NO. DIVISION UNITS FOR CELL STRENGTH
SF TILTING	S917	SAFETY FACTOR AGAINST TILTING
SF SLIDING	S907	" " " SLIDING
SF VERT SHEAR	S924	" " " VERTICAL SHEAR
S(N)	S922	VERTICAL SHEAR RESISTANCE
S(T)	S923	RESISTANCE AGAINST SLIPPAGE
M(R)	S911	RESISTING MOMENT AGAINST TILTING
P(W), SUMH	S903	LATERAL OUTBOARD FORCE (WATER)
P(R)	S905	PRESSURE AT BASE OF CELL DUE TO FILL
M(O)	S904	NET OVERTURNING MOMENT PER LIN.FT.
M(F)	S906	RESISTING MOMENT FROM INTERLOCK FRICTION
Q	S921	TOT SHEAR FORCE PER FT
MAX INTERLOCK STRESS	S920	MAXIMUM INTERLOCK STRESS AT THE BASE
SUMV	S930	NET WEIGHT OF CELL FILL

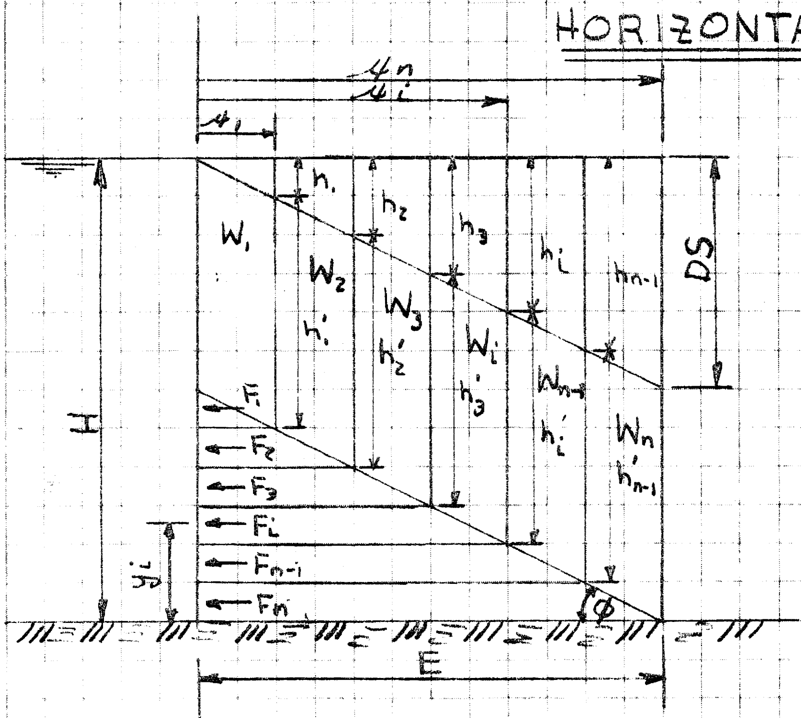
SUBJECT: COFFERDAM DESIGN

COMPUTATION: PROGRAM WRITE-UP MATHATRON CS III

COMPUTED BY: PRL CHECKED BY: DATE: 13 MAR 72

CELLULAR COFFER DAM
ON ROCK

HORIZONTAL SHEAR



INPUT VALUES

H = Height cell

E = Effective width cell

DS = Depth saturation line

ϕ = Angle of repose fill

NUMF = No of "i" divisions

" = n

TILTING RESISTANCE CELL FILL

$x_i = E \times i/n \qquad h_i = DS \times i/n \qquad h'_i = H - \tan\phi \times (E - x_i) - h_i$

$W_i = \gamma_{SUB} \times x_i \times h'_i + 1/2\, \gamma_{SUB} \times x_i \times h_i + 1/2\, \gamma_{SAT} \times x_i \times h_i$

$F_i = (W_i - W_{i-1}) \tan\phi$

$y_i = \tan\phi \times (E - x_i) + 1/2 \times \tan\phi \times E/n$

$$M_R = \sum_{i=1}^{n} F_i \times y_i$$

SUBJECT: COFFERDAM DESIGN

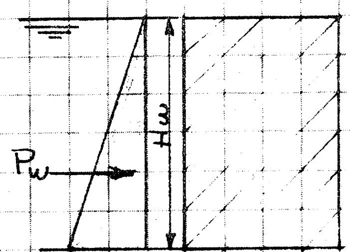
COMPUTATION: PROGRAM WRITE-UP MATHATRON CS III

COMPUTED BY: PBL CHECKED BY: DATE: 13 MAR 72

APPLIED FORCES & OVERTURNING MOMENTS

$P_w = 1/2 \times \gamma_{wat} \times H_{wat}^2$

$M_o = P_w \times H_{wat}/3$

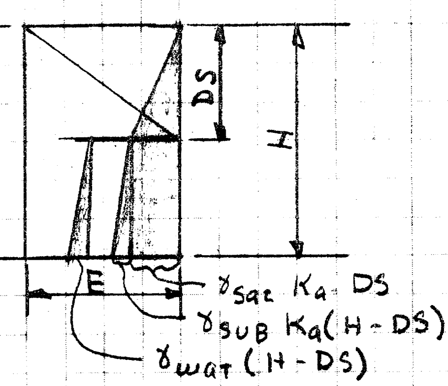


TILTING RESISTANCE INTERLOCK FRICTION

$P = [\frac{1}{2} DS + (H-DS)] * \gamma_{sat} K_a DS + (\gamma_{SUB} K_a + \gamma_{wat}) \frac{1}{2} (H-DS)^2$

$M_f = P \times f \times E$

f = coefficient interlock friction usually = .3



SAFETY FACTOR AGAINST TILTING

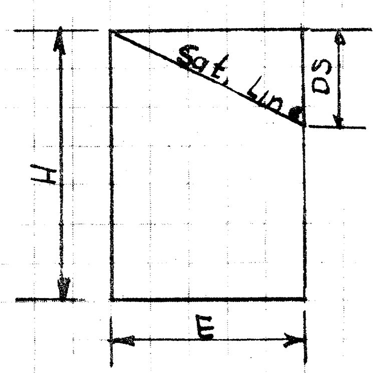
$N_T = (M_R + M_f)/M_o$

SAFETY FACTOR AGAINST SLIDING

$\Sigma V = 1/2 \times \gamma_{sat} \times DS \times E + 1/2 \times \gamma_{SUB} \times DS \times E + \gamma_{SUB} \times (H-DS) \times E$

$\Sigma H = P_w$

$SF = \tan\phi \times \Sigma V / \Sigma H$



SUBJECT COFFERDAM DESIGN

COMPUTATION PROGRAM WRITE-UP MATHATRON CS111

COMPUTED BY PRL CHECKED BY DATE 13 MAR 72

PILE INTERLOCK TENSION

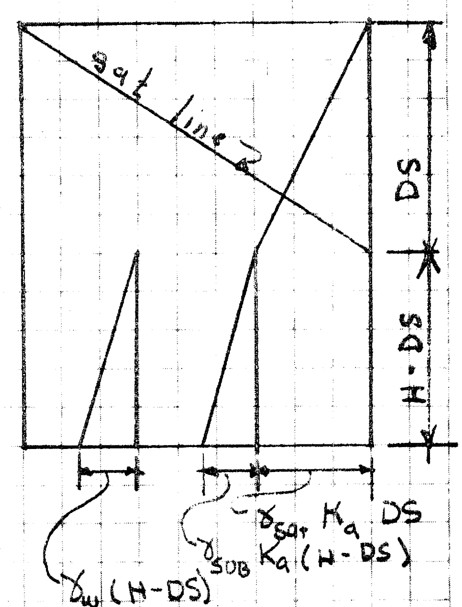
$P = \gamma_{sat} K\, DS + (\gamma_{SUB} K_a + \gamma_w)(H - DS)$

$L = D/2 + Z/2 \qquad \theta = 45^\circ \quad \sec\theta = 1.414$

$\text{Max } t = PL \sec\theta$

$\text{Stress} = \text{Max } t / 12$

Assumed max @ base of cell



VERTICAL SHEAR

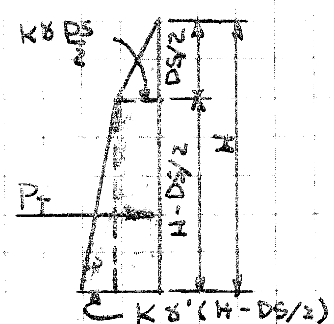
DRIVING SHEAR

$Q = 3M_o / 2E$

SHEAR RESISTANCE

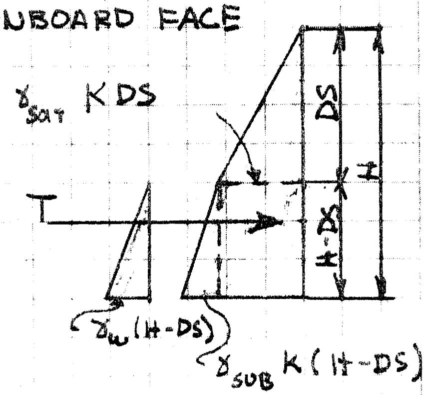
$K = \dfrac{\cos^2\phi}{2-\cos^2\phi}$

@ CENTERLINE P_T



$f = .3$
$n = 2.$
$r = D/2$

@ INBOARD FACE



$P_T = \frac{1}{2}\gamma_{sat} K \frac{DS^2}{4} + \gamma_{sat}\frac{DS}{2}(H - DS/2)K + 1/2\, \gamma_{SUB}(H - DS/2)^2 K$

$S_n = P_T \tan\phi$

$T = \gamma_{sat} K(DS)\left(\frac{1}{2}DS + (H-DS)\right) + \frac{1}{2}\gamma_w (H-DS)^2 + 1/2\, \gamma_{SUB}(H-DS)^2 K$

$S_T = T\, r f n / Y$

$G_s = \dfrac{S_n + S_T}{Q}$

PROGRAM LISTING

INPUT

```
N
"810
; U---------------,
;CELLULAR-COFFER-,
;DAM-ON-ROCK M J J,
; UREF:-EC-1110-,
;2-114----16-NOV-,
;70 M J J J UTITL,
;E: C: N((= M J J,
; UHT-CELL-(H)= C,
;:$0 UDIAM-CELL= C,
;:$1 M J UEFF-WI,
;DTH-CELL-(E)= C:,
;$2 UTANP= C:$3 M,
; J UY-DIST-(Y)= C,
;:$4 UHT-WAT-(H1,
;)= C:$5 M J UDEP,
;-SAT-LINE-= C:$950,
; M J USAT-UNIT,
;-WT-(W2)= C:$6 U,
;SUB-UNIT-WT-(W3),
;= C:$7 M J UWT-W,
;AT-(W1)= C:$913 U,
;K-ACTIVE-(K1)= C,
;:$914 M J UK-AT,
;-REST-(K2)= C:$916,
; UNUMF= C:$901,
;1$9020$906$911 M,
; J J UALL-UNITS-,
;ARE-IN-FT-KIPS-E,
;XCEPT-INTERLOCK-,
;STRESS-IN-KSI M J,
; J C+"940,
```

COMPUTATIONS

```
N
"940
;#902/#901**#950$903,
;#902/#901**2$904,
;#0-#3(#2-#904)-#903),
;#904*#7+#903,
;*#904*.5(#6+#7),
;$905#905-#906)#3,
;$907#3(#2-#904)+,
;.5*#3**2/#901)#907,
;$910#910+#911$911,
;#902+1$902#905,
;$906#901-#902$912"940,
;.5*#913*#5*#5$903,
;#903*#5/3$904,
;#0-#950/2)*#6*#914,
;*#950+(#7*#914+#913,
;)(#0-#950)(#0-#950),
;.5$905#905*.3*,
;#2$906#906+#911)/,
;#904$917#2*.5*#950,
;*(#6+#7)+(#0,
;-#950)#7*#2$930#930,
;*#3/#903$907,
;#6*#914*#950+(#7,
;*#914+#913)*(#0-,
;#950))*#4/2*1.414,
;/12$920,
;3*#904/2/#2$921,
;#0-#950/2<2)#7+,
;#950*#0*#6-#950,
;*#950/4*#6)#916,
;/2*#3$922,
;#0-#950<2)#913/2,
;+#6*#916*#950(#0-,
;#950/2)+#7/2(#0-#950),
;(#0-#950)#916)#1*.3/,
;#4$923,
;#922+#923)/#921$924,
;+"840,
```

OUTPUT

```
N
"840
; USUMV C%930 U--,
;--SUMH C%903 M J,
; J J U'HORIZ,
;ONTAL-SHEAR' C M,
; J J UTILTING-RE,
;SISTANCE-OF-CELL,
;-FILL C M J U---,
;M(R)=(W)(F) C%911,
; M J J UAPPLIE,
;D-FORCES-AND-OVE,
;RTURNING-MOMENTS,
; C M J U---P(WAT),
;=.5(W1)(H1)(H1),
; C%903 M J U---M(,
;O)=P(WAT)-X-H/3,
; C%904 M J J UTI,
;LTING-RESISTANCE,
;-INTERLOCK-FRICT,
;ION C M J U---P=,
;.5(W2)(H)(H)(K1),
; C%905 M J U-,
;--M(F)=.3(P)(E),
; C%906 M J J USA,
;FETY-FACTOR-AGAI,
;NST-TILTING C M,
; J U---N(T)=(M(R),
;+M(F))/M(O) C%917,
; M J J USAFETY,
;-FACTOR-AGAINST-,
;SLIDING C M J U-,
;--SSF=TANP-X-SUM,
;V/SUMH C%907 M,
; J J UPILE-INTERL,
;OCK-TENSION C M,
; J U---MAX-INTERL,
;OCK-STRESS=(P)(L),
;SEC-O-/12 C%920,
; M J J U'VERTICAL,
;-SHEAR' C M J J+"900,

"900
; UDRIVING-SHEAR M,
; J---Q=3M/2E C%921,
; M J J USHEAR,
;-RESISTANCE M J-,
;--S(N)=P(T)-X-TA,
;NP C%922 M J U--,
;-S(T)=.3(T)(N)/(,
;Y) C%923+"910?,

"910
; M J J USAFETY-F,
;ACTOR M J---G(S),
;=S(N)+S(T))/Q C%924,
; M J J L+"810?,
```

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

PAGE 1/9

SUBJECT Charles River Locks ...
COMPUTATION Ans to OCE Comments
COMPUTED BY PRL CHECKED BY ... DATE 21 Aug 72

STAGE 2 COFFERDAM

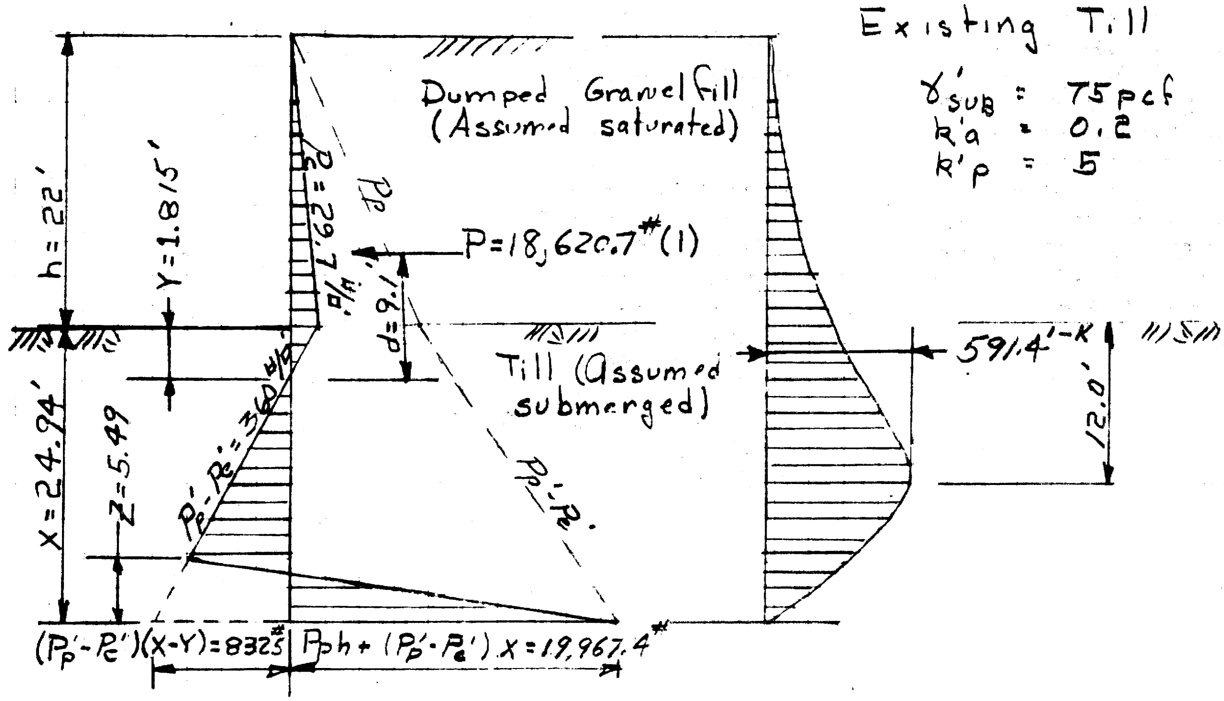
INTERIOR WALL

RESULTS OF COMPUTATIONS BASED ON ANALYSIS 2

Use: Mariner Steel $F_y = 50$ ksi
W14 x 158

Dumped Gravel fill:
$\gamma_{sat} = 135$ pcf
$k_a = 0.22$
$k_p = 3.7$

Existing Till
$\gamma'_{sub} = 75$ pcf
$k'_a = 0.2$
$k'_p = 5$



NET LOADING DIAGRAM MOMENT DIAGRAM

(not to scale)

(1) Modified to account for spaces between the vertical beams. see comps.

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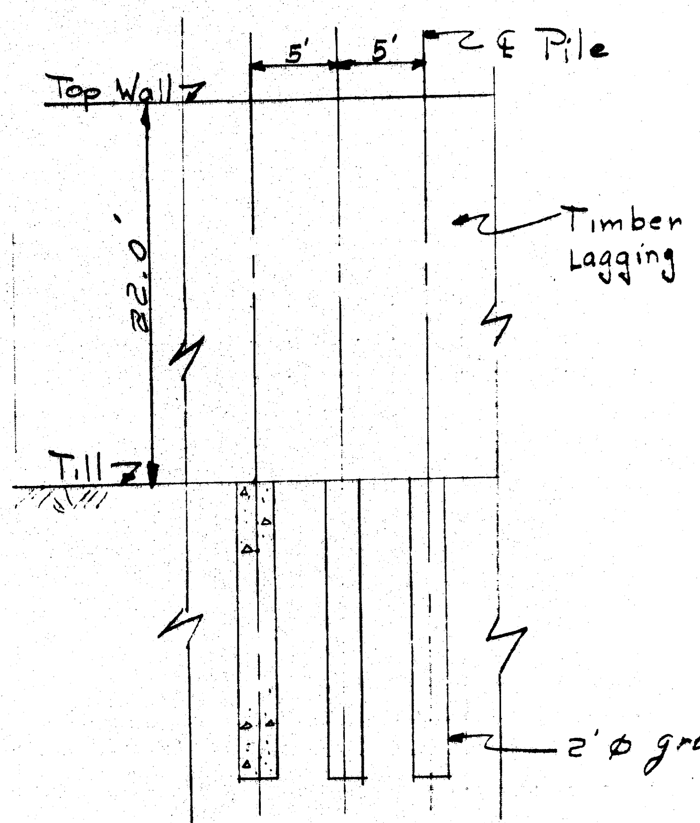
Rev. Aug 72

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Charles River Locks & Dam
COMPUTATION Stage 2 Cofferdam Interior Wall
COMPUTED BY PRL CHECKED BY N. J. N. DATE 21 Aug 72

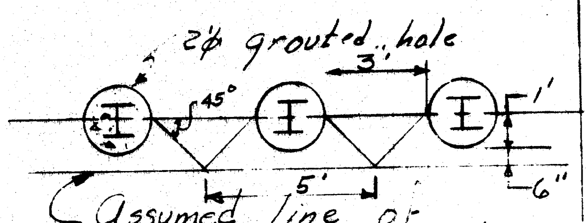
Stage 2 Cofferdam
Interior Wall



ELEVATION VIEW

Analysis 1

1' Strip - Uniform passive press.



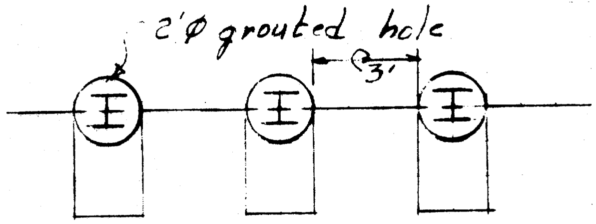
Assumed line of uniform passive pressure

Plan View

(For investigation only)

Analysis 2

Soldier bm - Proj. pass. resis.



Use Passive resistance projected from 2' ϕ conc encased ver. beam. only.

Plan View

A-19

(Design based on ~~this analysis~~)
Rev Aug. 72

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CORPS OF ENGINEERS, U.S. ARMY

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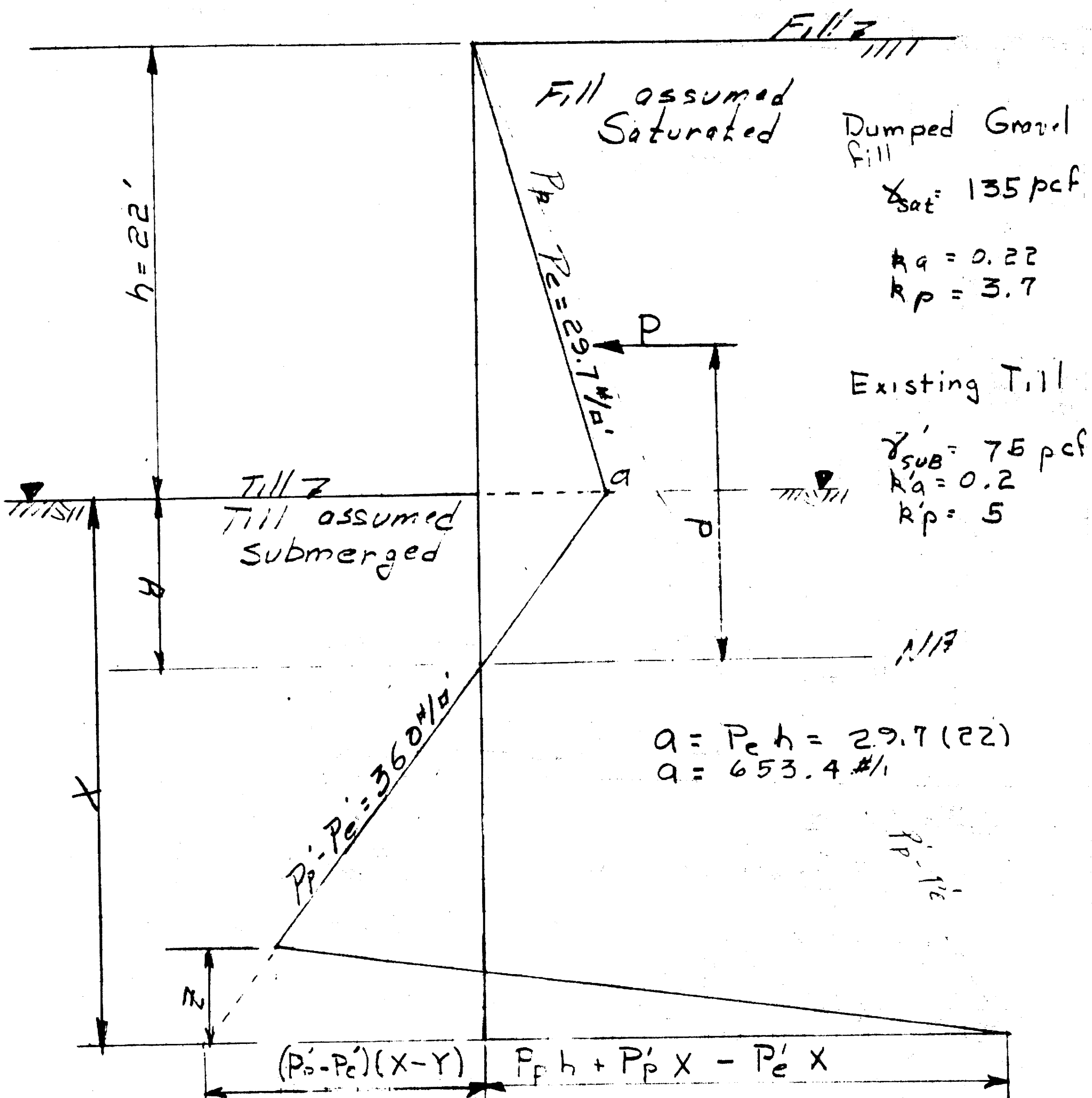
SUBJECT Charles River Locks & Dam
COMPUTATION Stage 2 Cofferdam Interior wall
COMPUTED BY PRL CHECKED BY [illegible] DATE 18 Aug 72

Interior Wall 1' strip analysis **Analysis 1**



$a = P_e h = 29.7(22)$
$a = 653.4$ #/1

$P_e = k_a \gamma_{sat} = .22 \times 135 = 29.7$ psf
$P_p = k_p \gamma_{sat} = 3.7 \times 135 = 499.5$ psf
$P'_e = k'_a \gamma_{SUB} = .2 \times 75 = 15.0$ psf
$P'_p = k'_p \gamma'_{SUB} = 5 \times 75 = 375$ psf

$y = \dfrac{a}{P'_p - P'_e}$

$y = \dfrac{653.4}{375 - 15}$

$y = 1.815'$

A-20
Rev. Aug. 72

Load acting at the centroid of the press diag. above the point y where ΣH & $\Sigma M = 0$.

$$P = \tfrac{1}{2} P_e h^2 + \tfrac{1}{2}(P_p' - P_e')\, y^2$$

$$= \tfrac{1}{2}(29.7)(22)^2 + \tfrac{1}{2}(360)(1.82)^2$$

$$P = 7780.4^{\#}$$

$$d = \frac{\tfrac{1}{2}(29.7)(22)^2\left[\tfrac{1}{3}(22) + 1.82\right] + \tfrac{1}{2}(360)(1.82)^2\left[1.82(2)/3\right]}{7780.4}$$

$$d = 9.10'$$

$$P = 7780.4^{\#}$$
$$d = 9.10'$$

THEORY - CAN BE USED FOR BOTH ANALYSIS 1 & 2

Equilibrium Eq. To determine min depth penetration:

$$\Sigma H = 0$$

$$P - \frac{(P_p' - P_e')(x-y)^2}{2} + \frac{z}{2}\left[(P_p' - P_e')(x-Y) + P_p h + (P_p' - P_e')X\right] = 0$$

Solving for z gives:

$$z = \frac{(P_p' - P_e')(x-y)^2 - 2P}{(P_p' - P_e')(X-Y) + P_p h + (P_p' - P_e')X}$$

$\Sigma M = 0$ Taking moments about the bottom of pile

$$P(d + x - y) - (P_p' - P_e')\tfrac{1}{2}(x-y)^3\tfrac{1}{3} + \frac{z^2}{6}\left[(P_p' - P_e')(x-Y) + P_p h + (P_p' - P_e')X\right] = 0$$

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SUBJECT Charles River Locks & Dam
COMPUTATION Stage 2 Cofferdam Interior Wall
COMPUTE

CSIII CHANNEL PROGRAMMING SHEET

TITLE Cantilever Sheet-Pile
PROGRAMMER P.R.L.

CHANNEL No S5
TAPE No

PAGE 1 OF 1
DATE 21 Aug 72

THEORY & FORMULAS

x	\$820	$P_p' - P_e'$	\$5
y	\$821	P_p	\$6
Z	\$3	P	\$844
h	\$823	d	\$845
x - y	\$7		

Check

Plate No 13 EC 1110-2-114

x = 10.04
y = 1.25
h = 10.0
x - y = 8.79

$P_p' - P_e'$ = 266.7 #/□'
P_p = 300.0 #/□'
P = 1873 #
d = 4.17'

[ΣM = 0
z = 2.10']

ΣM = 0 ≃ -8.104 OK
z = 2.102' OK

SECTOR \ STEP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0 (Z)	#	5	*	#	7	*	#	7	-	2	*	#	8	4	4	)
1 (Z)	/	(	#	5	*	#	7	+	#	6	*	#	8	2	3	+
2 (Z)	#	5	*	#	8	2	0	\$	3	?						
3 (ΣM)	#	8	4	4	*	(	#	8	4	5	+	#	7	)	-	#
4 (ΣM)	5	/	6	*	#	7	*	#	7	*	#	7	+	#	3	*
5 (ΣM)	#	3	/	6	(	#	5	*	#	7	+	#	6	*	#	8
6 (ΣM)	2	3	+	#	5	*	#	8	2	0	)	\$	0	:	?	
7																
7A																
7B																
7C																

NOTE: S1 TO S6 MAY BE TRADED FOR SECTORS 7A,7B,7C

Rev. Aug 72 A-21a

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SUBJECT Charles River Locks & Dam – Interior Wall
COMPUTATION Analysis-1 Find depth penetration & z dist
COMPUTED BY PRL CHECKED BY [illegible] DATE 21 Aug 72

1' strip Analysis

Analysis 1

FIND DEPTH PENETRATION REQUIRED

Given:

$h = 22.0'$
$y = 1.815'$
$P = 7780.4$ #
$d = 9.10$

$P_p' - P_e' = 360$ psf
$P_p = 499.5$ psf

Trial 1.

$x = 17'$ $x - y = 15.185'$

$\Sigma M = 0 \neq 12448.4$ N.G.

Trial 2.

$x = 18.0'$ $x - y = 16.185'$

$\Sigma M = 0 \neq -13295.9$ NG

Trial 3

$x = 17.50$ $x - y = 15.685$

$\Sigma M = 0 \cong 39.39$ O.K. FOR 1' STRIP

$z = 3.18$

Depth penetration req'd Analysis 1 = 17.50'
$z = 3.18$

SUBJECT Charles River Locks & Dam - Interior Wall

COMPUTATION Analysis 1 Find max moment & Sreq'd

COMPUTED BY PRL CHECKED BY H.J.H. DATE 24 Aug 72

Analysis 1

Find Max Moment:
(Use 2nd part of CS III program see pages 4 & 5 of comps)

Input constants:

$h = 22'$
$y = 1.815'$

$P = 7780.4^{\#}$
$d = 9.10'$

$P_p' - P_e' = 360$ psf
$P_p = 499.5$ psf

$z = 0$ (the max mom occurs above z dist)

Trial #	X (ft)	Mom (1-#)
1	10	101583.4
2	9	104448.6
3	8	104727.2
4	8.3	104893.8
5	8.4	104903.2 ← MAX.
6	8.41	104902.8

FIND Section Modulus Req'd

$F_b = .55\,F_y$

$S_{req} = M / F_b$

Tot Mom $= M_{max} \times 5 = 524.5'^{-k}$

Mariner Steel ($F_b = 27.5$)

$$S_{req} = \frac{524.5 \times 12}{27.5} = 229 \text{ in}^3$$

A-36 Steel ($F_b = 20$)

$$S_{req} = \frac{524.5 \times 12}{20} = 315 \text{ in}^3$$

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SUBJECT Charles River Locks & Dam - Interior Wall
COMPUTATION Analysis 2 Find depth penetration & z-dist
COMPUTED BY PRL CHECKED BY [illegible] DATE

Soldier beam Analysis Analysis 2

Assume that only the soil behind the 2' conc. encase[illegible] provides passive resistance.

Increase the load above the NA.
1/2 Spacing between Soldier piles in till fdn.

$= (5-2) \div 2 = 1.5$

$P_1 = \frac{1}{2}(29.7)(1.5)(22)^2 = 10781.1^{\#}$

$\bar{y} = \frac{1}{3}(22) = 7.33'$

$y = 1.82'$ $\bar{y} + y = 9.15'$

Use arm = 9.10

$\therefore P_1 = 10781.1 \times 9.15 \div 9.10 = 10,840.3^{\#}$

For prog: $P = P + P_1 = 7780.4 + 10840.3$
$P = 18620.7^{\#}$

Trials:

$h = 22'$ $P = 18620.7^{\#}$ $P_p' - P_a' = 360$ psf
$y = 1.815'$ $d = 9.10$ $P_p = 499.5$ psf

① $x = 25'$ $x - y = 23.185'$

$\Sigma M = 0 = -2962.8$ NG.

② $x = 24.95$ $x - y = 23.135'$

$\Sigma M = 0 = -414.2$ NG.

③ $x = 24.94$ $x - y = 23.125$

$\Sigma M = 0 = 93.96$ OK. $z = 5.488'$

Analysis 2 Results:
Depth of penetration required = 24.94
$z = 5.49'$

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SUBJECT: Charles River Lock & Dam - Interior Wall
COMPUTATION: Analysis 2 Find Max Mom & Sxx req'd
COMPUTED BY: PRL CHECKED BY: N.J.H. DATE: 21 Aug 72

Analysis 2

Find Max Moment:

Input constants:

$h = 22'$
$y = 1.815'$

$P = 18620.7^{\#}$
$d = 9.10'$
$P_p' - P_e' = 360$ psf
$P_p = 439.5$ psf

$z = 0$
(max moment occurs above z)

Trial #	X (ft)	Mom. (1-#)
1	15	282499.
2	14	287792.
3	13	293763.
4	12	295708. ← Max.
5	11	293986.

Max Mem $= 295.7^{1-K}$
for 1' width of pile

$2 \times 295.7 = 591.4$

Use Mariner Steel $F_b = 27.5$ ksi

Tot. Mom $= 591.4^{1-K}$

$S_{req} = M/f_b$

$S_{req} = \frac{591.4}{27.5} \times 12 = 258.1 \text{ in}^3$

Use: Mariner Steel
W 14 x 158

W 14 x 158
$S_{xx} = 253 \text{ in}^3 \simeq 258$

A-21e
Rev. Aug. 72

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27 Sept 49

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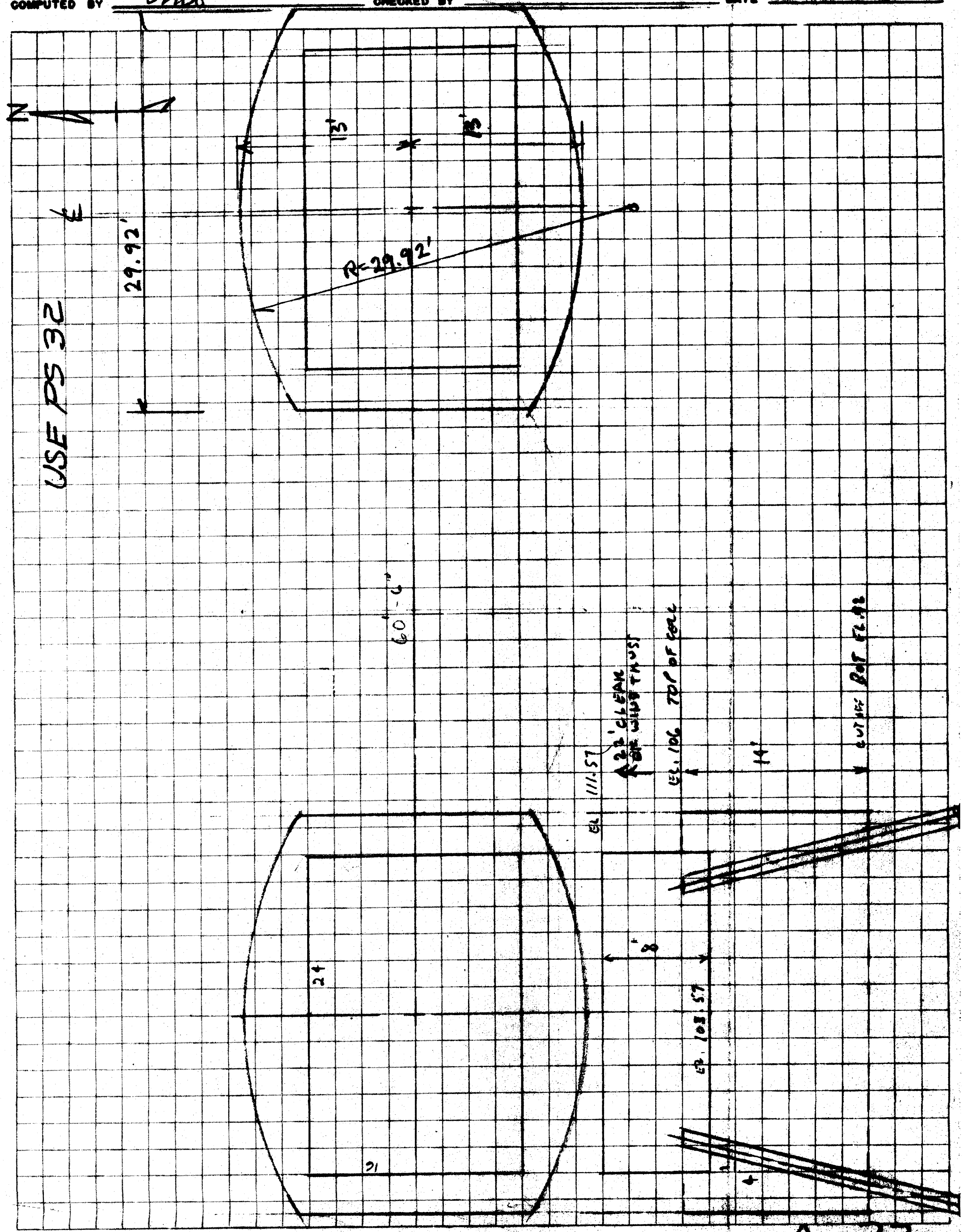
CORPS OF ENGINEERS, U. S. ARMY

PAGE 1/2

SUBJECT CHARLES RIVER DAM

COMPUTATION FITZGERALD EXPRSWAY BENT #1 - PROTECTIVE 30' DIAPHRAGM CELL

COMPUTED BY [signature] CHECKED BY DATE 31 MAR 72

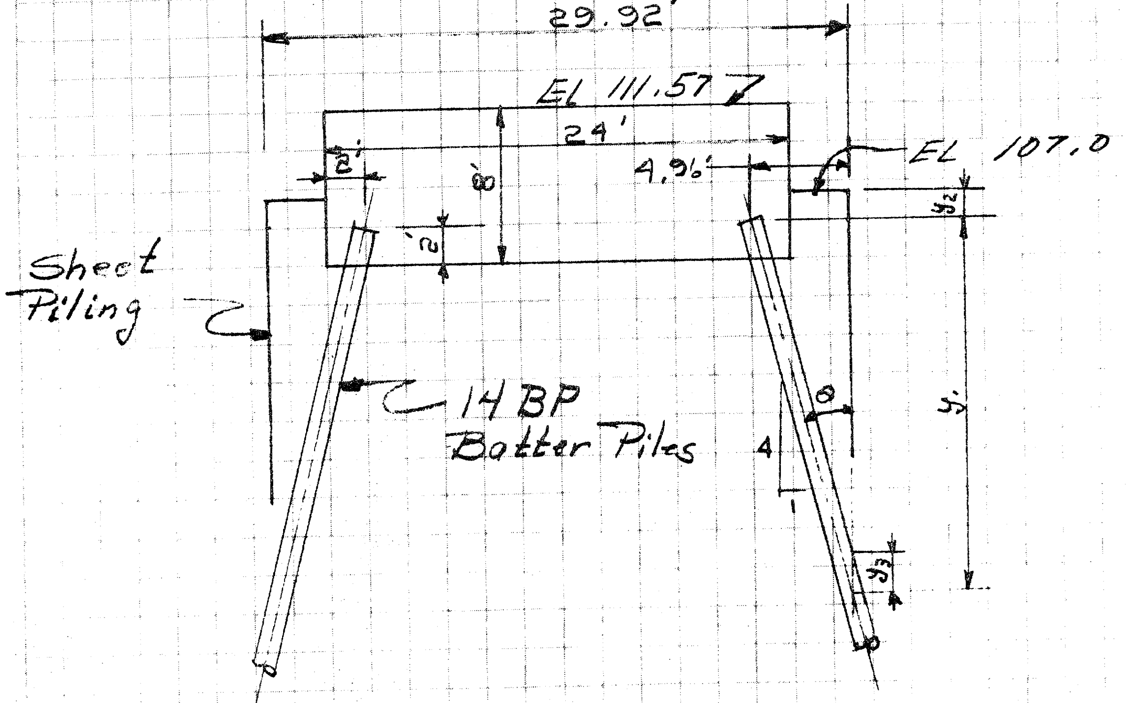


SUBJECT Charles River Locks & Dam

COMPUTATION Max length for sheet piling @ Bent #1 at Expressway

COMPUTED BY PL CHECKED BY DATE 4/10/72

Ans. USE 14'



BENT #1

1. Ver dist fr top of 14BP batter pile to intersection of ℄ with sheet piling:
$y_1 = 1/4 \times 4.96 = 19.84'$

2. Ver dist fr top of 14BP batter pile to top of sheet piling:
$y_2 = 107 - 103.57 - 2' = 1.43'$

3. Verdist fr intersection ℄ of 14BP & sheet piling to face of batter pile:
$y_3 = 7'' \times \frac{1}{12''/'} \times \sin\theta$
$\tan\theta = .25 \therefore \theta = 14°3' \therefore \sin\theta = .243$
$\therefore y_3 = 2.4'$

4. For a 1' hor. clearance with batter pile need 4' ver dist. fr face of pile

5. Max sheet piling length:
$= 1.43 + 19.84 - 2.4 - 4 = \underline{14.87'}$

CHARLES RIVER COFFERDAM

DEFLECTION ANGLES FROM CENTERLINE OF CELLS

FOR R ~~MP-103~~ PSX32 STEEL SHEET PILING
CELL DIAMETER= 49.026 FEET
DRIVING DISTANCE= 16.5 INCHES

INCREMENT= 3.21429: TOT NO= 35:

INC NO	ANGLE	DEGREES	MINUTES	SECONDS
1	3.21429	3	12	51.44
2	6.42858000	6	25	42.88
3	9.64287000	9	38	34.33
4	12.8571600	12	51	25.77
5	16.0714500	16	4	17.22
6	19.2857400	19	17	8.66
7	22.5000300	22	30	.10
8	25.7143200	25	42	51.55
9	28.9286100	28	55	42.99
10	32.1429000	32	8	34.44
11	35.3571900	35	21	25.88
12	38.5714800	38	34	17.32
13	41.7857700	41	47	8.77
14	45.0000600	45		.21
15	48.2143500	48	12	51.66
16	51.4286400	51	25	43.10
17	54.6429300	54	38	34.54
18	57.8572200	57	51	25.99
19	61.0715100	61	4	17.43
20	64.2858000	64	17	8.88
21	67.5000900	67	30	.32
22	70.7143800	70	42	51.76
23	73.9286700	73	55	43.21
24	77.1429600	77	8	34.65
25	80.3572500	80	21	26.10
26	83.5715400	83	34	17.54
27	86.7858300	86	47	8.98
28	90.0001200	90		.43
29	93.2144100	93	12	51.87
30	96.4287000	96	25	43.32
31	99.6429900	99	38	34.76
32	102.857280	102	51	26.20
33	106.071570	106	4	17.65
34	109.285860	109	17	9.09
35	112.500150	112	30	.54

CHARLES RIVER COFFERDAM 9/MARCH 72

LINE FROM ANCHOR CELL TO EAST CROSSOVER

```
C "820:
TRAVERSE
TEAR OFF TAPE
NORTH= -91.5000000:  EAST= -128.000000: ← ANCHOR CELL COORDINATE
CELL LINE FR CELL #21 TO #15
D= 321.180000:  BRG=  80.0000000:21.0000000:25.6700000:  Q= 2.00000000:
-53.7997220:316.642041:-145.299722:188.642041:
CELL LINE FR CELL #15 TO #14
D= 53.5300000:-1:  A=  -9.0000000:38.0000000:34.3300000:
.000000000&41:53.5300000:-145.299722:242.172041:
CELL LINE FR CELL #14 TO #13
D= 53.5300000:-1:  A=  -19.0000000:17.0000000:8.66000000:
17.6798595:50.5260677:-127.619863:292.698108:
CELL LINE FR CELL #13 TO #41
D= 53.5300000:-1:  A=  -102.000000:51.0000000:26.2000000:
45.3250677:-28.4798030:-82.2947960:264.218305:
                       COORDINATE
D=
```

LINE FROM ANCHOR CELL TO ~~E~~ WEST CROSSOVER

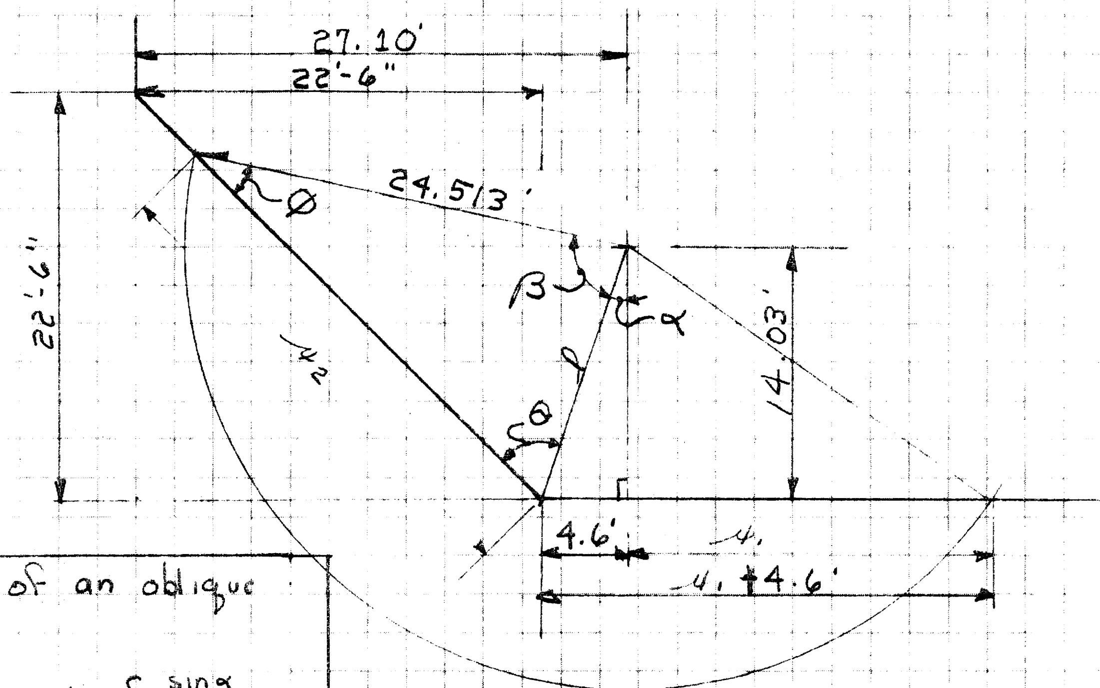
```
((\"820:
TRAVERSE
TEAR OFF TAPE
NORTH= -91.5000000:  EAST= -128.000000: ← ANCHOR CELL COORDINATE
CELL LINE FR #21 TO WEST CROSSOVER PARTIAL CELL
D= 53.5300000:  BRG=  19.0000000:17.0000000:8.66000000:  Q= 1.00000000:
50.5260677:17.6798600:-40.9739323:-110.320140:

D=

L
```

NOTE: EQUIP. – MATHATRON CSIII
PROG. – TRAVERSE PROG FROM CIVIL ENGR. PACKAGE PROVIDED BY MATHATRONICS

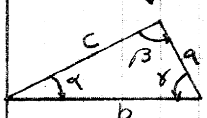
SUBJECT Charles River Cofferdam
COMPUTATION WEST CROSSOVER (BASIN END) - CONNECTIONS
COMPUTED BY PRL CHECKED BY ______ DATE 12 May 72

WEST CROSSOVER - BASIN END

I



Properties of an oblique triangle:



$\sin\gamma = \dfrac{c \sin\alpha}{a}$

$\beta = 180 - (\alpha + \gamma)$

$b = \dfrac{a \sin\beta}{\sin\alpha}$

1. $\ell_1 = ?$ $\quad 24.513^2 = \sqrt{\ell_1^2 + 14.03^2}$

$\ell_1 = \sqrt{24.513^2 - 14.03^2}$

$\ell_1 = 20.1'$

$\ell_1 + 4.6 = 24.7'$

$\ell_1 = 20.1'$

$\ell_1 + 4.6 = 24.7'$

2. $\ell_2 = ?$

$\tan\alpha = 4.6/14.03 = 0.3279$

$\therefore \alpha = 18° - 9'$

$\therefore \theta = 45° + (18° - 9')$

$\theta = 63° - 9'$

$\ell = \sqrt{14.03^2 + 4.6^2} = 14.765'$

SUBJECT Charles River Cofferdam
COMPUTATION WEST CROSSOVER (BASIN END) - CONNECTION
COMPUTED BY PRL CHECKED BY DATE 12 May 72

$$\sin \phi = \frac{14.765 \sin(63^\circ\text{-}9')}{24.513} = 0.5374$$

$$\therefore \phi = 32^\circ\text{-}30'$$

$$\beta = 180 - [(63^\circ\text{-}9') + (32^\circ\text{-}30')]$$

$$\therefore \beta = 84^\circ\text{-}21' = 84.35^\circ$$

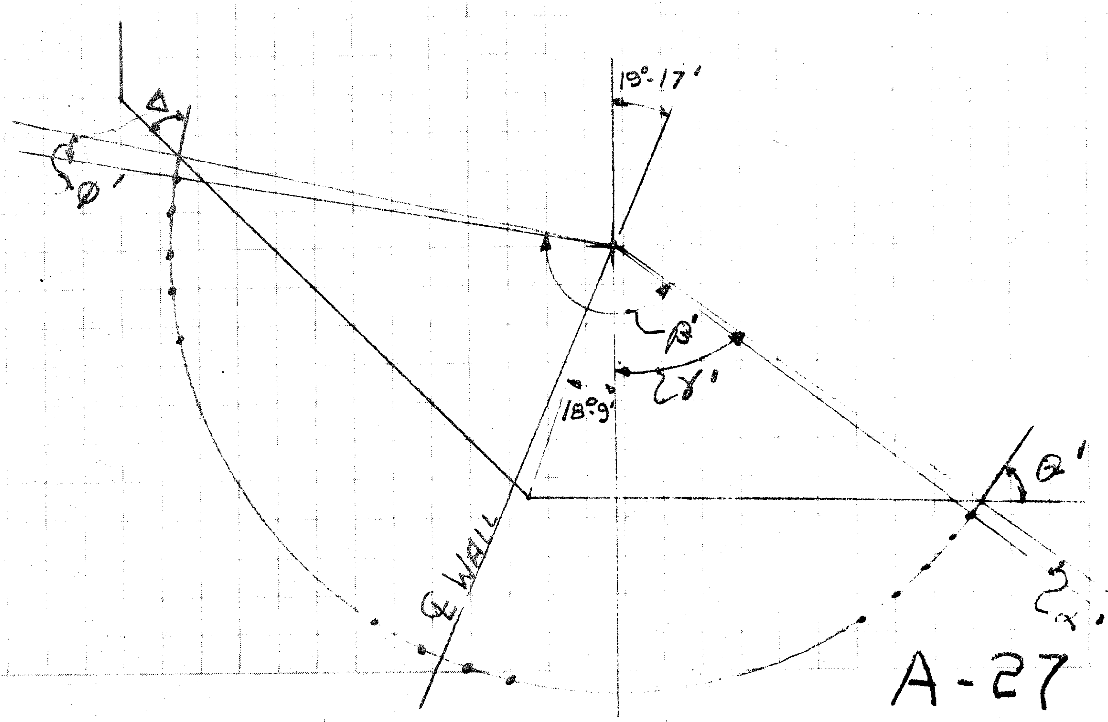
$$y_2 = \frac{14.765 \sin(84^\circ\text{-}21')}{\sin(32^\circ\text{-}30')} = \frac{14.765(.99514)}{.5373}$$

$$\therefore y_2 = 27.346' = 27'\ 4''$$

$$\underline{\underline{y_2 = 27'\text{-}4''}}$$

II

WEST CROSSOVER



SUBJECT Charles River Cofferdam
COMPUTATION WEST CROSSOVER (BASIN END) - CONNECTIONS
COMPUTED BY PRL CHECKED BY DATE 12 May 72

TRY: 48 MP-103 STEEL SHEET PILING FOR WEST CROSSOVER

$\beta' = 48 \times 3.21429^\circ$

$\beta' = 154^\circ - 17' = 154.283^\circ$

Angular difference between ℄ cofferdam wall and the corner of concrete wall

$= 19^\circ 17' - 18^\circ 9' = 1^\circ - 8' = 1.13^\circ$

1. $\phi' = (84.35^\circ - 1.13^\circ) - (\underbrace{80.357^\circ}_{\text{25 MP.103 SHEETS}} + \frac{3.214}{2})$

$= 1.25$

$\phi' = 1^\circ - 15'$

$s_1 = R\phi' = 24.513\,(1.25) \times \frac{3.1416}{180} \times 12$

$s_1 = 6.41''$ say $6\frac{1}{2}''$

$\Delta = 32.5^\circ + 90^\circ = 122.5^\circ = 122^\circ - 30'$

2. $\theta' = 180 - (\tan^{-1} \frac{14.03}{20.1} + 90^\circ)$

$= 180 - (90 + \tan^{-1} .6976)$

$= 180 - (124 - 54')$

$\theta' = 55^\circ\ 6'$

$\gamma' = \sin^{-1} \left(\frac{20.1}{24.513}\right) = \sin^{-1} .820 = 55^\circ\ 6'$

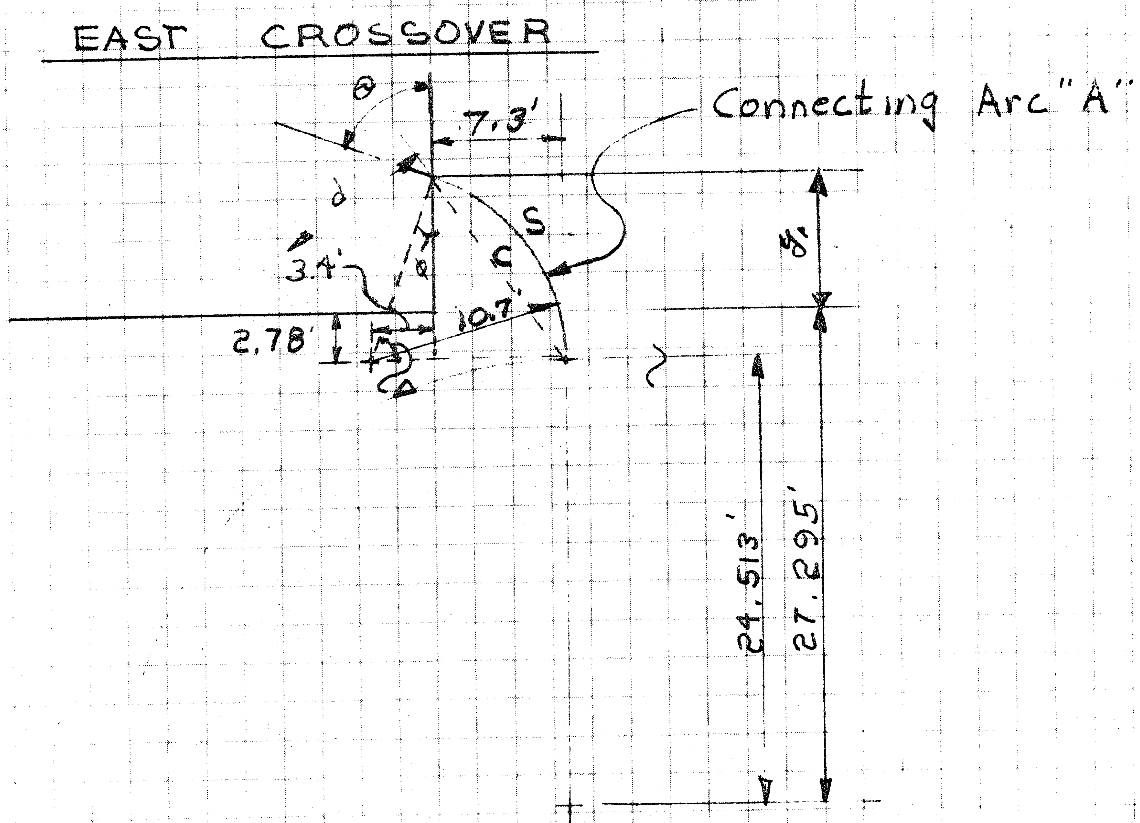
$\alpha' = 55.1^\circ - \left(154.283^\circ - (80.357 + \frac{3.214}{2}) - 19.283\right)$

$\alpha' = 2.064^\circ = 2^\circ\ 4'$

$s_2 = R\alpha = 24.513\,(2.064)\left(\frac{3.1416}{180}\right)(12)$

$s_2 = 10.60$ say $10\frac{1}{2}''$

SUBJECT CHARLES RIVER COFFERDAM
COMPUTATION EAST CROSSOVER (TIDE END) CONNECTIONS
COMPUTED BY PRL CHECKED BY DATE May 72



Connecting Arc "A"

1. $y_1 = \sqrt{10.7^2 - 3.4^2} - 2.78$ (≈ 10.145')

$y_1 = 7.365' = 7'-4\frac{1}{2}"$ ±

$\underline{\underline{y_1 = 7'-4\frac{1}{2}"}}$

2. $C = \sqrt{7.3^2 + 10.145^2} = 12.498'$

$d = \frac{1}{2}\sqrt{4(10.7)^2 - 12.5^2} = 8.69'$

$S = D \cos^{-1} d/R = 2(10.7) \cos^{-1} \frac{8.69}{10.7}$

$= 21.4(.623) = 13.33'$

$\Delta = S/R = 13.33/10.7 = 71.38°$

$\underline{\underline{\Delta = 71.38°}}$

SUBJECT CHARLES RIVER COFFERDAM

COMPUTATION EAST CROSSOVER (TIDE END) CONNECTION

COMPUTED BY PRL CHECKED BY DATE MAY 72

3. USE 9 MP103 SHEET PILES

$\Delta'_4 = 7.363 \times 9 = 66.267^\circ$

$S' = 16\frac{1}{2} \times 9 \div 12 = 12.375'$

$S - S' - 6'' = 13.33 - 12.375 - .5$

$S - S' = .455' = 5\frac{1}{2}''$ Proj Sht $= 5\frac{1}{2}''$

4. $\phi = \sin^{-1} \frac{3.4}{10.7}$

$\phi = 18.6^\circ$

$\theta = 180 - 90 - 18.6$

$= 71.4^\circ$

$\theta = 71^\circ 24'$

5. DIST FROM END CULVERT

$= 7.365' - 6' = 1.365'$

$= 1' - 4\frac{1}{2}''$

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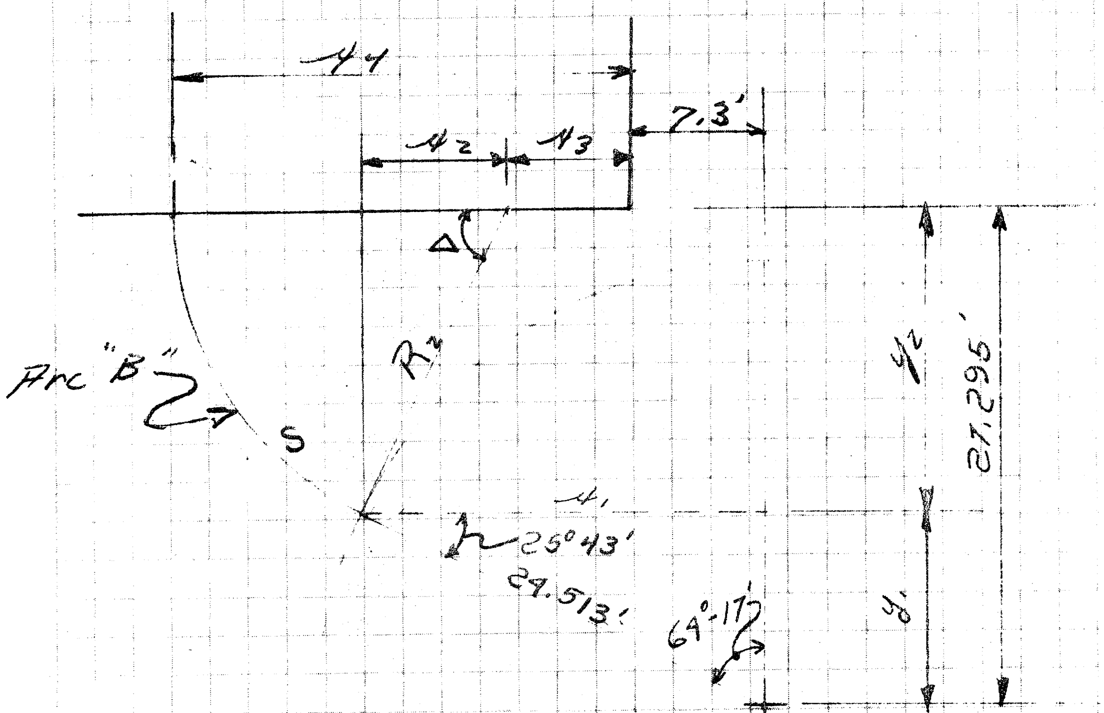
SUBJECT CHARLES RIVER COFFERDAM

COMPUTATION EAST CROSSOVER (TIDE END) CONNECTIONS

COMPUTED BY PRL CHECKED BY DATE May 72

EAST CROSSOVER - CONNECTING ARC B



1. $x_1 = \cos(25°43') \times 24.513 = 21.928'$

$y_1 = \sin(25°43') \times 24.513 = 10.957'$

$y_2 = 27.295 - 10.957 = 16.338'$

$x_2 = y_2 / \tan^{-1}(64°\text{-}17') = 7.816'$

$x_3 = x_1 - 7.3 - x_2 = 21.928 - 7.3 - 7.816$

$x_3 = 6.812'$

$R_2 = \sqrt{7.816^2 + 16.338^2} = \underline{18.111'}$

$x_4 = 18.111 + 6.812 = 24.923'$

$= \underline{\underline{24'-11''}}$ A-31

2. $\Delta = 64^\circ 17'$

$S = R\theta = 18.111\,(64.283)\left(\frac{3.1416}{180}\right)$

$S = 20.32'$

Use 14 PSX32 Piles 16½" driving dist.

$\Delta' = \frac{16.5 \times 14}{12 \times 18.111} \times \frac{180}{3.1416} = 60.9^\circ$

$S' = 14 \times 16.5 = 19.25'$

$S - S' - 6'' = 20.32 - 19.25 - .5$

$= .57' = 6.84''$

say $6\frac{3}{4}''$